THREE ESSAYS ON RISK PREMIUMS IN THE SECURITY MARKETS

BY

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I dedicate this dissertation to my parents, my wife, and my children, Jennie and Stephen.

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This dissertation consists of three related but independent essays on the nature of the risk premiums in the financial market, particularly the role of the risk premiums in determining asset prices.

The first essay examines whether the nature of risk premiums in the foreign exchange market is invariant with respect to the maturity of the forward contracts. Using the joint Generalized Method of Moments (GMM) to the overlapping samples of different maturities, the hypothesis that forward foreign exchange rates are unbiased predictors of future spot rates is rejected. Joint tests across currency and across maturity also confirm not only the existence of time-varying risk premiums but that the variation in the forward premiums rather than movements in expected spot exchange rate changes accounts for most of the volatility in foreign exchange rates. The resolution of uncertainty in the foreign exchange market is not uniform across maturity and there is maturity specific information investors can use in their investment decisions.

The second essay examines the effect of the Federal Reserve's

weekly money supply announcement on the foreign exchange rates and risk premiums in the international capital market equilibrium. The spot exchange rates and risk premiums increase simultaneously after unexpected increase in the money supply. This evidence is consistent with the hypothesis suggested by the interest rate parity theory and the real interest rate theory of money supply announcement effect. The Federal Reserve's stated monetary policy significantly affects the market reaction to monetary shocks.

The third essay addresses the price relationship between the primary and derivative assets and the dealers' risk premiums in the Treasury bill markets. The study on the forward-futures yield differentials shows that the possibility of market segmentation between the spot and futures market is not prevalent. The market segmentation hypothesis is not rejected for the subsample of negative monetary shocks, but the change in yield differential is too small to reach the conclusion of market segmentation.

The effect of money supply announcements on the bid-ask spread is analyzed to study the nature of dealers' risk premiums. The bid-ask spread of spot bills declines, but not statistically significantly, after announcements. The Fed's release of monetary information does not contribute to the resolution of uncertainty or the market expectations are so efficient that the announcement does not contain valuable information for the future interest rate movement.

CHAPTER I
INTRODUCTION

Security prices have been characterized by the risk return relationship. The premiums which compensate security holders for bearing the risk of uncertainty play an important role in determining the asset prices.

The risks include future price risk, default risk, and inflation or purchasing power risk. By risk-free assets we usually mean assets free from default risk. The future price risk is an important factor in pricing the risk free assets. Prices of default-risk free securities such as the U.S. Treasury bills keep fluctuating until the maturity date with the fluctuations of market interest rates (interest rate risk). Even for the securities with positive but almost equal default-risk such as Euro-currency loans price risk still matters.

In this dissertation, the focus is on the role of price risk in determining the asset prices. By restricting our attention to nominal prices and returns, we abstract from purchasing power risks. The dissertation consists of three related essays on the role of risk premiums in pricing of securities.

The objective of Chapter II is to test whether the nature of risk premiums in the foreign exchange market is invariant with respect to the maturity of the forward contracts and to examine the possibility that risk premiums in the forward foreign exchange market move in proportion to a single latent variable.

The existence of premiums in the forward foreign exchange rates has been extensively studied since the beginning of the flexible exchange rate system. The existence of premiums also has direct implication to the efficiency of the foreign exchange market and to the predictability of forward foreign exchange rates for the future spot rates. Efficiency in the foreign exchange market implies that forward foreign exchange rates are market prediction of future spot rates. However, there is a general agreement that forward exchange rates have little if any predictive power for the future spot rates. The lack of forecasting power of forward exchange rates for the change in the future spot rates is considered as an evidence to the existence of premiums in the forward rates. Many empirical studies documented not only that the premiums exist but that the premiums are time varying. However, previous studies on this subject are restricted to the shortest maturity forward contracts (one month) due to the sample size problem of longer maturities.

The first part of Chapter II extends the study of the nature of time variation in risk premiums into the multi-maturity framework using the Generalized Method of Moments (GMM) procedure of Hansen (1982). To the extent that maturity-specific risk premiums are identified, the analysis can uncover the presence of market segmentation. Furthermore, most of the fluctuations in the foreign exchange markets can be attributed to the arrival of new maturity-specific information and the nature of the information can have differential impact on forward contracts of different maturities. The study on the longer maturity forward contracts is possible using overlapping sample. The GMM is required to handle the statistical problems of overlapping sample. The

multi-period forecasting errors in the overlapping sample cause autocorrelation which cannot be cured by conventional econometric techniques. Also, the GMM is an appropriate method for the conditional heteroscedasticity. The existence of conditional heteroscedasticity in the foreign exchange market has been found.

In the second part of Chapter II, the evidence of time-varying risk premiums in the forward foreign exchange rates is extended to the single latent variable model to assess the co-movement of risk premiums proportion to a single variable. The single latent variable can be interpreted as a constant beta on a single, unobservable benchmark portfolio in the context of the Intertemporal Capital Asset Pricing Model (ICAPM).

The objective of Chapter III is to examine the effect of the weekly money supply announcement on the foreign exchange rates and on the premiums in the forward foreign exchange market. The accumulated evidence shows that increases in unanticipated money stock persistently lead to increases in nominal interest rates. Given the Fisher relationship linking nominal interest rate to expected real interest rate and expected inflation rate, the explanation of the observed relationship could only be due to the two sources. The expected real rate effect suggests that the monetary authorities intend to reverse the unanticipated increase in the future with the result that real rates are anticipated to increase. On the other hand, if the Federal Reserve is unable or unwilling to counteract the unanticipated increase, the increase in nominal interest rates could be attributed to an expected increase in future inflation. Unfortunately, studies utilizing fixed-income securities have been unable to discern adequately the two

alternative explanations of the effect of unanticipated money supply announcements on nominal interest rates.

By jointly examining the spot and forward exchange markets of different maturities, the possibility of over-adjustments in the spot exchange market is examined. This possibility is due to the differential price adjustments between the financial and the commodities markets. Spot rates have the characteristics of financial markets and therefore respond to change in expectations of future market fundamentals. They may, therefore, overreact to compensate for the slow adjustment in the commodities markets to unexpected shocks.

The second issue in Chapter III is the effect of monetary uncertainty on the risk premiums in the forward exchange market. This objective can be accomplished by investigating any change in the characteristics of risk premiums in the forward foreign exchange market around the Federal Reserve's weekly money supply announcements.

The objective of Chapter IV is two-fold. The first one is to test the hypothesis that market segmentation between the U.S. Treasury bill spot and futures market determines the yield spreads between the forward and futures interest rates. The second objective is to assess the information contents of the Federal Reserve's weekly money supply announcements in relation to the bid-ask spreads in the spot Treasury bill quotes.

Both the yields on Treasury bill futures contracts and the implied forward rates embodied in the term structure of interest rates covering the same future period contain the information about market expectations of future interest rates. Previous literature on the efficiency of Treasury bill futures market found the existence of yield differentials

between the Treasury bill spot and futures contracts. Previous studies attempted, but in vain, to explain the yield spreads by institutional constraints such as differential tax treatments, margins and marking to market in the futures market, and transactions costs (arbitrage costs). The regular event of money supply announcements provides a unique opportunity to examine whether the Treasury bill spot and futures markets are segmented. Market segmentation means that the two markets are comprised of two distinct non-overlapping groups and they behave differently in expectations formation and in pricing of risk premiums for the same information events. By focusing on the changes in the yield spread, not on the yield spread itself, we can abstract from institutional constraints which are mostly unobservable. The natural hypothesis is that the Treasury bill futures contracts, as a derivative asset to the spot Treasury bills, react to the monetary information in the same manner as the spot bills do. Significant changes in the forward-futures yield spread around the announcements are evidence of market segmentation between the two markets.

The second issue in Chapter IV is the relationship between the bid-ask spread of the spot Treasury bills and the monetary uncertainty. Bid-ask spread in the Treasury bill market can be decomposed into dealers' real costs and risk premiums. Real costs include operation expenses and the opportunity costs of funds tied up in the inventory of securities. Security dealers carry a certain amount of inventory to provide immediacy for their customers. Risk premium means the compensation for the expected losses of inventory value from unexpected declining of prices and unexpected increases in interest rates. The expected losses are a positive function of interest and price

uncertainty. They are expected to charge risk premiums by widening bid-ask spreads when the degree of informational uncertainty is high. The evidence of systematic changes in the bid-ask spread around the money supply announcement will reveal the information contents of the Fed's announcements and the Treasury bill dealers' pricing behavior with respect to the information uncertainty. If the Fed's announcements have an information contents and serve as a resolution of monetary uncertainty, then the bid-ask spreads will decrease after the announcements.

The final chapter contains the conclusions of the present study. It summarizes the results and includes suggestions for the further research.

CHAPTER II
RISK PREMIUMS IN THE FOREIGN EXCHANGE MARKET

Introduction

Since the era of flexible foreign exchange rates, there has been considerable political, commercial and academic interest in the efficiency of the forward foreign exchange markets. Policy makers are concerned that excessive speculation in the forward exchange market results in unwarranted volatility in the spot exchange market, and the predictability of forward exchange rates in forecasting the future spot exchange rates is used in arguments against intervention by central banks.

Early studies by Frenkel (1977) and Levich (1979) supported the proposition that the forward rate was an unbiased predictor of the future spot rate which was taken as an indication of the efficiency of the market. There is growing literature showing that forward exchange rates are systematically biased predictors of future spot exchange rates when expectations are posited to be rational. The unbiasedness hypothesis is rejected in many empirical studies (Dooley and Shafer (1983), Cumby and Obstfeld (1981), Bilson (1981), and Fama (1984)). Theoretically, numerous international asset pricing models demonstrate that the bias is the risk premium, possibly time varying, risk-averse investors receive as compensation for the risk inherent in forward exchange rate speculation. Unfortunately, despite the general agreement over the significance of the risk premiums, few of these theoretical

specifications are empirically tractable and the rejection of unbiasedness hypothesis has not been considered as an acceptance of a particular risk premium model. In an important contribution to the literature, Fama (1984) showed that the nature of the risk premiums can be further understood without the need to utilize a particular model. Specifically, Fama decomposed the forward premium into two unobservable components: the expected spot exchange rate and the risk premium. He not only found the risk premium to be time-varying but that its variations rather than movements in expected spot exchange rates account for most of the volatility in one-month forward premiums. The results are further supported by Hodrick and Srivastava (1986) employing different methodologies. However, these studies examined just one-month maturity forward contract. In contrast, the foreign exchange markets are characterized by trading in forward contracts of numerous maturities.

The purpose of this chapter is to determine if the nature of time variation in risk premiums is invariant with respect to the maturity of the forward contracts. This is accomplished by studying the relative variation in the risk premium and the expected future spot components of forward rates and the covariation between the two for forward contracts of various maturities. This has numerous implications for the foreign exchange markets. To the extent that maturity-specific risk premiums are identified, the analysis can uncover the presence of market segmentation. In short, it may very well be that the observed volatility in the risk premiums occurs only in the one-month forward rates. Furthermore, most of the fluctuations in the foreign exchange markets can be attributed to the arrival of new maturity-specific

information and the nature of the information can have differential impacts on forward contracts of different maturities. For example, surprise changes in short-term interest rates will likely affect only short term forward contracts.

An obvious problem in using contracts of longer maturities is the corresponding decline in the number of observations with nonoverlapping forecast errors. For example, with twelve-month forward contracts, less than 15 observations are available for the current floating exchange rate period.[1] On the other hand, the standard generalized least squares cannot be used to adjust for the serial correlation in the residuals induced by the overlapping data. This is because when the regressors are predetermined but are not strictly exogenous, generalized least squares produces inconsistent estimates.

In this chapter, we capitalize on the availability of weekly data and scrutinize the testable restrictions by using the Generalized Method of Moments (GMM) procedure suggested by Hansen (1982) that yields consistent and relatively efficient asymptotic estimates. The present paper therefore extends prior analysis of one-month contracts using weekly data. Since previous tests rely on the asymptotic distribution theory, with the four-fold increase in sample size the adequacy of the previous data can be addressed. In addition, a number of studies have found that conditional heteroskedasticity is present in foreign exchange rates data. The GMM is also appropriate in that it yields estimates

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[1]All previous findings are subject to the question of the statistical validity of the test since they were based on asymptotic distribution theory. This limitation on the number of observations induced Hodrick and Srivastava (1985) to study the nature of risk premiums in the foreign exchange futures market.

that are robust with respect to conditional heteroskedasticity. Since the various forward exchange markets do not operate in isolation, it is important to allow for the interactions between them. Accordingly the estimations are performed simultaneously for various forward maturities for each exchange rate as well as different exchange rates for each maturity. This is achieved by extending the GMM to the case of joint estimation.

Hypotheses, Data, and Econometric Issues

Hypotheses

The forward exchange rate F_t observed at time t for an exchange at t+k is the market determined certainty equivalent of the future spot exchange rate S_{t+k}. The forward rate can be decomposed into two part: expected future spot exchange rate and a risk premium.

(1) $f_t = E(s_{t+k}) + p_t$,

where $f_t=\log(F_t)$, $s_{t+k}=\log(S_{t+k})$, p_t is the risk premiums, and the expected future spot rate, $E(s_{t+k})$, is the rational forecast, conditional on all information available at t.[2] Using (1) the forward premium is

(2) $f_t-s_t = E(s_{t+k}-s_t)+p_t$.

From the following two regression equations Fama (1984) drew testable restrictions to assess the role of forward premiums in the determination of forward rates.

(3) $f_t-s_{t+k} = a_1 + b_1(f_t-s_t) + e_{1,t+k}$,

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[2]Natural logs are used in (1) to make the analysis independent of whether exchange rates are expressed as units of domestic currency per unit of foreign currency or vice versa. Logarithm also transforms the foreign exchange rate series to more stationary series.

(4) $s_{t+k}-s_t = a_2 + b_2(f_t-s_t) + e_{2,t+k}$.

Since the sum of dependent variables of (3) and (4) is the common independent variable, the sum of the intercepts in (3) and (4) is zero and the sum of the slope coefficients is one. In other words, the two equations contain identical information about two components in the forward premium: variation in the risk premium and the expected future spot exchange rate. Dependent variable in (3), f_t-s_{t+k}, is the premium, p_t, plus random forecast errors, $E(s_{t+k})-s_{t+k}$. Evidence that b_1 is significantly different from zero or equivalently that b_2 is significantly different from one implies the existence of time-varying risk premiums. Then the null hypothesis for the existence of time-varying risk premiums is

(5) H_0 : $b_1=0$ or $b_2=1$.

It is also shown in Fama (1984) that the relative magnitude of variations of premium and expected change in spot exchange rate can be expressed as the difference between two slope coefficients,

$$(6) \quad b_1-b_2 = \frac{\mathrm{var}(p_t) - \mathrm{var}(E(s_{t+k}-s_t))}{\mathrm{var}(f_t-s_t)}$$

Evidence that b_1-b_2 is significantly greater than zero means that variation of risk premium is larger than that of the expected rate of change of the future spot exchange rate. Then the null hypothesis for the test of relative magnitude of the variation of risk premiums and the variation of expected future spot rate changes is

(7) H_0 : $b_1-b_2 = 1-2b_2 \leq 0$.

Data

Weekly data for the 9 spot and forward foreign exchange rates come from the Weekly Review of the Harris Trust and Savings Banks. Friday close exchange rates of U.S. dollar per foreign currency are used. The sample period begins August 31, 1973, which coincides with Fama's (1984) study and ends May 9, 1986. Four maturities for forward contracts are available. For the nonoverlapping sample, one-, three-, six-, and twelve-month forward rates are sampled at 4, 13, 26, and 52 weeks interval, respectively. Data availability for the twelve-month contracts limits its starting date to September 6, 1974.

Econometric Issues

To conserve notation, let us define the following variables.

$y_{t+k} = s_{t+k} - s_t$ = the vector of change in spot exchange rates from t to t+k,

$x_t = f_t - s_t$ = the vector of m forward premiums observed at time t,

e_{t+k} = the vector of innovation in y_{t+k}

I_t = the information set available at time t,

b = an m-dimensional column vector of parameters.

Consider the problem of estimating the parameters of a k-period ahead forecasting equation,

(8) $E(y_{t+k} | I_t) = x_t b$, or equivalently

$$y_{t+k} = x_t b + e_{t+k}.$$

Under the rational expectations, y_{t+k} can be written as its conditional expectation ($E(y_{t+k} | I_t)$) plus a mean zero forecast error (e_{t+k}) uncorrelated with any variable in the information set I_t. It can be shown that $E(e_{t+k} e_{s+k})$ is zero for all $|t-s| \geq k$. Only in the case when

the sampling interval is the same as the forecasting interval, that is, k=1, will the forecast errors be serially uncorrelated.

Under the presence of serial correlation, the Ordinary Least Squares (OLS) estimators are consistent, but asymptotic variance-covariance matrix is inconsistent. Consequently, in testing hypothesis concerning forecasting equations, one alternative is to define the sampling interval to be equal to the forecast interval. This alternative clearly does not use all available data.

A standard econometric technique for estimation in the presence of serial correlation is the Generalized Least Squares (GLS). The GLS in the time series data requires the strict econometric exogeneity of $\{x_t\}$ process. This means that $E(e_{t+k} | x_t, x_{t-1}, x_{t+1}, \ldots) = 0$. This strict assumption means that knowledge of future x_t's would be useless in determining the optimal forecast for y_{t+k}. In the study of the exchange market the assumption of strict exogeneity is clearly inappropriate since knowledge of future values of these variables would provide useful information in forecasting future spot exchange rates. If the x_t vector contains variables which are predetermined but not strictly exogenous, the GLS adjustment for the serial correlation produces inconsistent estimator.

The estimation strategy in this chapter is to obtain consistent estimators using all available sample or data sampled more finely than the forecast errors. To handle the serial correlation problem of multi-period ahead forecast equation the Generalized Method of Moments (GMM) of Hansen (1979) is required. By making the appropriate adjustment in the estimation of the asymptotic covariance matrix, we can increase

dramatically the sample size of the data used and hence increase the asymptotic power of the tests.

Empirical Procedures and Results

Nonoverlapping Sample Estimation

It is natural to believe that there are strong correlations among currencies since, in addition to arbitrage activities in the exchange market, all exchange rates are measured in terms of the U.S dollar and most countries tend to control their exchange rates relative to one another. So an appropriate joint test that takes into account the cross-currency correlation is warranted. Table 2-1 reports the coefficients estimate of (4) obtained by applying the Seemingly Unrelated Regression (SUR) to 9 currencies for each maturity.

For one-month forward contracts, all slope coefficients, except the French franc, are negative and all significant coefficients are close to minus one. All intercept terms are close to zero although four are significantly different from zero. For three- and six-month forward rates, no clear pattern has emerged as has been the case of one-month forward rates. There is no distinctive pattern in the sign of slope coefficients and only three coefficients are negative and significant at 10% level. As we move to long-term forward contracts, the number of observations decline proportionately. For twelve-month forward rates only 11 observations are available and small sample size keeps us from making reliable inferences. Despite the lack of reliability, the result from twelve-month forward contracts is similar to that from one-month data. All negative slope coefficients are significant at 5% significance level.

Table 2-1
Cross-Currency Estimation: SUR

Maturity

	1 month N=165		3 month N=50		6 month N=25		12 month N=11	
	a	b	a	b	a	b	a	b
CD	-0.003	-1.391	-0.006	0.330	-0.012	0.433	-0.024	0.599
	(0.001)	(0.535)	(0.003)	(0.518)	(0.005)	(0.531)	(0.012)	(0.519)
BP	-0.005	-1.042	-0.020	-1.537	-0.037	-1.474	-1.045	0.025
	(0.003)	(0.518)	(0.008)	(0.597)	(0.020)	(0.744)	(0.038)	(0.512)
BF	-0.002	-0.654	-0.006	-0.363	-0.009	0.065	-0.038	-1.070
	(0.003)	(0.208)	(0.008)	(0.357)	(0.019)	(0.488)	(0.038)	(0.311)
FF	-0.002	0.252	-0.005	0.669	-0.017	0.265	-0.079	-0.942
	(0.003)	(0.255)	(0.008)	(0.352)	(0.020)	(0.394)	(0.040)	(0.273)
DM	0.004	-0.904	0.003	-0.212	0.004	-0.093	0.069	-1.945
	(0.003)	(0.283)	(0.008)	(0.401)	(0.020)	(0.442)	(0.036)	(0.334)
IL	-0.008	-0.289	-0.021	-0.026	-0.028	0.360	-0.087	0.076
	(0.003)	(0.195)	(0.008)	(0.254)	(0.021)	(0.319)	(0.040)	(0.255)
DG	0.002	-0.809	0.007	-1.064	0.009	-0.664	0.010	-0.914
	(0.003)	(0.214)	(0.007)	(0.309)	(0.018)	(0.340)	(0.036)	(0.252)
SF	0.008	-1.134	0.024	-1.097	0.057	-1.388	0.229	-3.560
	(0.004)	(0.441)	(1.102)	(0.529)	(0.027)	(0.604)	(0.054)	(0.640)
JY	0.003	-0.309	0.010	-0.451	0.017	-0.168	0.086	-2.064
	(0.002)	(0.332)	(0.009)	(0.448)	(0.020)	(0.588)	(0.035)	(0.581)

Notes: Numbers in parentheses are standard errors
N = Number of observations
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-2
Cross-Currency Test: SUR Estimation

	Null Hypothesis		
	$b_i=b_j$	$b_i=1.0$	$b_i=0.0$
Maturity	$X^2(8)$	$X^2(9)$	$X^2(9)$
1 month N=165	18.65 (0.02)	182.15 (0.00)	36.73 (0.00)
3 month N=55	23.74 (0.00)	80.41 (0.00)	25.75 (0.00)
6 month N=25	15.38 (0.05)	44.67 (0.00)	14.45 (0.08)
12 month N=11	87.60 (0.00)	357.46 (0.00)	118.88 (0.00)

Notes: Numbers in parentheses are marginal significance levels
N = number of observation.

Table 2-2 shows chi-square tests on various joint hypotheses on the slope coefficients. The hypothesis that all slope coefficients are equal to one another is rejected for all maturity at 10% significance level.[3] This means that even after considering cross-currency correlation, forward exchange rates reveal country-specific movements. The hypothesis that all b_2 are equal to one is rejected for all maturities. Regarding the fact that many coefficients are significantly negative, it is nor surprising. However, given an efficient exchange market, the deviation of b_2 from 1.0 is a direct measure of the variation of the premium in the forward rates. Also it is widely recognized that b_2 being significantly different from 1.0 may be due to the existence of time-varying risk premiums in the forward foreign exchange rates. The hypothesis that all b_2 are zero is also rejected at conventional confidence level. This hypothesis is equivalent to a hypothesis that all b_2 are negative as an one-tail test. Decisive rejection of this hypothesis affirms, but for all maturities, Fama's (1984) finding of unresolved issue that negativity of b_2 is the result of negative correlation between the premium (p_t) and the expected spot exchange rate change ($E(s_{t+k}-s_t)$) components of forward premium (f_t-s_t).

<u>Overlapping Sample Estimation</u>

As pointed out earlier, the results on the long-maturity forward rates are subject to the statistical validity due to the small sample size. Furthermore, cross-maturity study is infeasible since only a few observations are available for the joint estimation. To compromise the

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[3]Using F test, Fama (1984) could not reject this hypothesis. His study was only for the one-month forward rates with 122 observations.

sample size and the statistical problems caused by overlapping sample, the GMM procedure is used. The GMM procedure produces consistent estimates from serial correlation and conditional heteroscedasticity. Standard econometric technique implicitly assumes that the disturbance $\{e_t\}$ is homoscedastic with respect to the instruments, so that

(9) $E(e_t^2 | X_t) = \sigma_e^2$, for all t.

Condition (9), however, will hold, for example, when the disturbance and instruments are jointly normally distributed. An advantage of the GMM is that it avoids some restrictive assumptions concerning the covariance matrices of residuals

As has been the case of the SUR estimation of nonoverlapping sample, joint estimation of overlapping sample produces more efficient estimates and allows cross-currency and cross-maturity joint tests. Table 2-3 reports correlation coefficients of residuals from single equation GMM estimation of each currency for different maturities. Except for the Canadian dollar, all 8 currencies are highly correlated even after adjustment of serial correlation and conditional heteroscedasticity. Furthermore, the nature of cross-currency correlation is invariant with respect to maturity. Evidence from Table 2-3 warrants the necessity of the cross-currency joint GMM estimation. Simultaneous estimation of 9 currencies for each maturity can be accomplished by extending single equation GMM estimation into the SUR framework.

Using previously defined notations, define the vector function $h(y_{t+k}, x_t, b^*) = e_{t+k}$

(10) $h(y_{t+k}, x_t, b^*) = y_{t+k} - a - bx_t$,

where b^* is the 18 element vector of parameters (a_1 b_1 ... a_9 b_9). The model provides orthogonality conditions that can be used for estimation of b in (10).

Let $z_t' = (1\ x_{1t}\ \ldots\ x_{9t})$ be the 10 elements vector of instruments, and define the function f by

(11) $f(y_{t+k}, x_t, b^*) = h(y_{t+k}, x_t, b^*) \otimes z_t$,

where $\otimes$ is the Kronecker product of matrix.

The model implies

(12) $E[f(y_{t+k}, x_t, b^*)] = 0$

when f is evaluated at the true parameter vector b^*. This is a vector of 90 orthogonality conditions formed from the unobservable error terms. The GMM estimator exploits the sample moment of (12) defined by

$$(13) \qquad g_T(b) = (1/T) \sum_{t=1}^{T} f(y_{t+k}, x_t, b)$$

for a sample of size T.

The parameters are chosen to minimize the criterion function,

(14) $J_T(b) = g_T(b)' W_T g_T(b)$

for an appropriately chosen 90X90 symmetric weighting matrix W_T. The optimal choice of W_T is described in Hansen (1982). The optimal W_T is chosen in a way to minimize the asymptotic covariance matrix of the parameters for the class of estimators that exploit the same orthogonality conditions.

$$(15) \qquad W_T = \{(1/T) \sum_{t=1}^{T} f(y_{t+k}, x_t, b) f(y_{t+k}, x_t, b)'\}^{-1}$$

In the context of the SUR procedure, the model can be written as

(16) $Y = Xb^* + e$,

where Y is the 9T-dimensional column vector of y_{it} (i=1,...9, and t=1,...,T), e is the 9T-dimensional column vector of e_{it}, and X is the 5Tx18 block diagonal matrix which has X_i as its i-th diagonal matrix and X_i is itself the Tx2 matrix of (1, x_{it}). Define the instrument matrix Z as the 5Tx90 block diagonal matrix which has Z_i (i=1,...,9) as its diagonal matrix and Z_i itself is the Tx10 matrix of (1, $x_{1t}, \ldots, x_{9t}$). Then the orthogonality conditions are

(17) $g_T(b^*) = Z'(Y-Xb^*)/T,$

and the GMM estimates, b_T, can be obtained by minimizing the criterion function

(18) $J_T(b^*) = (1/T)^2(Y-Xb^*)'ZW_TZ'(Y-Xb^*),$

where the weighting matrix W_T is

(19) $W_T = \{ \sum_{K=-L+1}^{L-1} (1/T) \sum_{t=1}^{T-K} (\hat{e}_t \otimes z_t)(\hat{e}_{t-k} \otimes z_{t+k})' \}^{-1}$

where $\hat{e}_t$ is a consistent estimates of e.[4]

Then the GMM estimates are

(20) $b_T = (X'ZW_TZ'X)^{-1}X'ZW_TZ'Y,$

and the asymptotic covariance matrix for $\sqrt{T}(b_T-b^*)$ is

(21) $V(b_T) = (D_T'W_TD_T)^{-1}$, where $D_T = Z'X/T$.

However, when the number of lag, L, is positive, there is no guarantee that the computed variance-covariance matrix will be positive definite. This can happen when autocovariances dominate own variances.

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[4]The OLS residuals are used to estimate the weighting matrix. Another alternative is to use the residuals from the SUR. Also, in actual estimation of weighting matrix, we only need to calculate the matrix sum for K=0,...,L-1 since the matrix sum over K=1,...,L-1 is a transpose of the matrix sum over K=-L+1,...,-1.

A positive definite matrix can be obtained by multiplying weighting matrix by modified Bartlett lag window, w(P),

(22) $$w(P) = \left| \frac{L+1-|K|}{L+1} \right|^P \qquad K=-L, -L+1,\ldots,L-1,L$$

to give less weight to the higher-order autocovariances of estimated residuals.[5] After a lag window adjustment weighting matrix becomes

(23) $$W_T = \{ \sum_{K=-L+1}^{L-1} w(P)\,(1/T) \sum_{t=1}^{T-K} (\hat{e}_t \otimes z_t)(\hat{e}_{t-k} \otimes z_{t+k})' \}^{-1}$$

It also needs to be noted that consistency is preserved through the lag window transformation.

Test of joint hypothesis can be accomplished by imposing cross-equation linear restrictions such as $Rb_T = r$ and utilizing the Wald test. R is a qXm restriction matrix with q restrictions and r is a q-dimensional column vector. Then the test statistic

(24) $$(Rb_T - r)'[RV(b_T)R'/T]^{-1}(Rb_T - r)$$

has the chi-square distribution with degrees of freedom equal to the number of restrictions (q) or the row dimension of matrix R.

The estimated variance-covariance matrices are not positive definite for L=12 and the triangular lag window (P=1.0) is used. Table 2-4 reports the joint estimation of 9 currencies for each maturity. For the one-month forward contract, 8 exchange rates are negative and significant, 7 currencies at 5% significance level and 1 currency at the 10% level. Due to the sample size, the more reliable comparisons

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[5]When P=0, there is no lag window adjustment. When P=1, w(P) is called a triangular or a tent lag window. When P is infinity, the weight matrix is a null matrix and no serial correlation is adjusted.

between overlapping and nonoverlapping estimations can be performed for the one-month forward rates. For the one-month rate data, overall results are very similar to each other. The French franc, which has insignificant positive slope coefficient in the SUR estimation, has negative but insignificant slope coefficient. The Japanese yen's slope coefficient, which is insignificant in the SUR estimation, is negatively significant only at 10% level. As to the magnitude of slope coefficients, all significant GMM estimates are larger than all significant SUR estimates. The one-month estimation result shows that the GMM and the SUR produce almost identical result and we can draw reliable inferences from overlapping data for long-term maturity forward rates.

Contrary to the SUR estimation of three-month forward rates, all slope coefficients are negative and significant for the three-month GMM estimation. For the six- and twelve-month forward rates data, all exchange rates except for the Canadian dollar have negative and significant slope coefficients. The sign of intercept terms are identical for two estimation methods regardless of the maturity. Significantly negative slope coefficients in Table 2-4 implies that the covariation between forward premiums and expected spot rate changes is negative and the magnitude of covariation is greater than the variation of expected spot rate changes for all maturities.

Table 2-5 also reports chi-square tests on various joint hypotheses on the slope coefficients. Table 2-5 is the replication of Table 2-2 from overlapping sample. The hypothesis that all the slope coefficients are equal is rejected for all maturities. The hypothesis that all the slope coefficients are equal to one is also rejected for all maturities.

Table 2-4 indicates that the nature of risk premiums in the foreign exchange forward rates is the same across currencies in the sense that they all have the time-varying components in them. However, the quantitative effects of forward premiums on the future spot exchange rates differ among currencies.

To see the relative magnitude of the variation of risk premiums and the variation of expected future spot rate changes, the hypothesis

(25) $H_0 : \quad var(p_t) < \; var(E(s_{t+k}-s_t))$

is tested and reported in Table 2-6. The hypothesis is equivalent to the one that b_1-2b_2 is negative and the test is implemented by estimating the one-tailed t-value of b_1-2b_2. The test in the SUR estimation of the one-month nonoverlapping sample shows that except the French franc the null hypothesis is rejected for all other exchange rates. As we move to long-term maturity forward rates, the null hypothesis is not rejected for more exchange rates. The test in the GMM estimation of overlapping sample shows that the null hypothesis is rejected only for the six and twelve-month forward rates. Along with Table 2-5, Table 2-6 reveals that both the premium, p_t, and the expected changes in the spot rate, $E(f_{t+k}-s_t)$, in forward premium, f_t-s_t, vary through time, and $var(p_t)$ is large relative to $var(E(s_{t+k}-s_t))$.

The cross-maturity joint estimation allows us to incorporate any contemporaneous correlation of maturity-specific information. As pointed out before, the biggest disadvantage of nonoverlapping sample is the lack of enough observations for various tests. Particularly, for the cross-maturity tests, only 11 observations are available for our sample period. Hence, the GMM is essential for the cross-maturity tests. Table 2-7 reports cross correlation coefficients of residuals

from single equation GMM estimation of each maturity for 9 currencies. As has been the case of the cross-currency estimation, the residuals are highly correlated. Residuals from adjacent forward premiums (diagonal terms in the correlation matrices) are more highly correlated than those from distant forward premiums (off-diagonal terms in the correlation matrices). Furthermore, the nature of cross-maturity correlation is invariant with respect to currency. Evidence from Table 2-7 warrants the necessity of the cross-maturity joint GMM estimation. Simultaneous estimation of 4 maturities for each currency can be accomplished by extending single equation GMM estimation into the SUR framework. Since the forecasting horizons increase for the long maturity forward contracts the maximum lags of 52 (L=52) are used for the estimation of single equation residuals and the variance-covariance matrix.[6] So, the estimates of standard errors are conservative measures. Table 2-8 reports the cross-maturity estimation of the GMM for each exchange rate. Except for the Canadian dollar all slope coefficients are negative but are less significant than cross-currency estimation.

Various joint hypothesis on the slope coefficients are tested and reported in Table 2-9. The hypothesis that the slope coefficients are equal across maturity for each currency is rejected for the 4 maturities. The rejection of this hypothesis implies that the resolution of uncertainty in the forward exchange market is not uniform across maturity for some currencies. It can happen only if there exists

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[6]Frequency domain approach can be used to obtain the weighting matrix. Spectrum and cross-spectrum of e'Z series at frequency zero is the estimates of covariance matrix in the frequency domain. This method, however, is not appropriate for our purpose since we have to estimate (90)(91)/2 number of spectral density functions.

maturity-specific information and the market has ability to differentiate it from one another with respect to maturity. The hypothesis that all slope coefficients are equal to one across maturity is rejected for all exchange rates. So the existence of time-varying risk premiums is confirmed and the nature of risk premiums in the foreign exchange market remains the same whether we incorporate the cross-currency correlation or the cross-maturity correlation.

Table 2-10 reports the test of the hypothesis in (25). Except for the Canadian dollar and the French franc, the hypothesis that the variation of risk premiums is smaller than the variation of expected changes in spot rates is rejected. Except for the longer term forward rates of the Canadian dollar and the French franc, the variation in the risk premiums dominates the variation in the expected spot rate changes. Together with Table 2-6 and Table 2-10, we can conclude that $var(p_t)$ is reliably greater than $var(E(s_{t+k}-s_t))$.

Table 2-3
GMM Single Equation Residuals' Correlation Coefficients
(Cross-Currency Correlation)

Panel A: Lower triangular matrix is for the 1 month forward rate
Upper triangular matrix is for the 3 month forward rate

	CD	BP	BF	FF	DM	IL	DG	SF	JY
CD		0.093	0.101	0.012	0.115	0.002	0.127	0.202	-0.034
BP	0.293		0.594	0.580	0.625	0.627	0.647	0.620	0.446
BF	0.241	0.629		0.863	0.944	0.778	0.923	0.825	0.585
FF	0.237	0.607	0.888		0.852	0.845	0.847	0.752	0.582
DM	0.230	0.622	0.943	0.876		0.782	0.970	0.868	0.585
IL	0.188	0.617	0.801	0.843	0.802		0.812	0.700	0.560
DG	0.244	0.653	0.936	0.883	0.968	0.812		0.861	0.588
SF	0.234	0.616	0.841	0.796	0.884	0.742	0.874		0.627
JY	0.106	0.450	0.602	0.615	0.598	0.570	0.595	0.624	

Panel B: Lower triangular matrix is for the 6 month forward rate
Upper triangular matrix is for the 12 month forward rate

	CD	BP	BF	FF	DM	IL	DG	SF	JY
CD		-0.193	-0.085	-0.162	-0.008	-0.198	-0.004	0.013	-0.195
BP	-0.040		0.709	0.790	0.740	0.855	0.729	0.732	0.586
BF	0.017	0.608		0.929	0.947	0.859	0.912	0.813	0.543
FF	-0.079	0.649	0.891		0.900	0.933	0.875	0.800	0.545
DM	0.021	0.637	0.953	0.870		0.883	0.982	0.885	0.554
IL	-0.138	0.679	0.824	0.876	0.829		0.886	0.789	0.567
DG	0.077	0.614	0.893	0.832	0.939	0.830		0.865	0.578
SF	0.174	0.649	0.801	0.764	0.840	0.706	0.863		0.647
JY	-0.093	0.428	0.546	0.543	0.558	0.548	0.543	0.607	

Notes: CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-4
Cross-Currency Estimation: GMM

Maturity

	1 month N=659		3 month N=650		6 month N=637		12 month N=558	
	a	b	a	b	a	b	a	b
CD	-0.003 (0.001)	-1.841 (0.306)	-0.007 (0.001)	-0.176 (0.097)	-0.012 (0.000)	0.485 (0.037)	-0.023 (0.000)	0.981 (0.012)
BP	-0.006 (0.001)	-1.400 (0.233)	-0.019 (0.001)	-1.670 (0.089)	-0.034 (0.001)	-1.466 (0.028)	-0.058 (0.001)	-0.811 (0.012)
BF	-0.002 (0.001)	-0.915 (0.103)	-0.007 (0.001)	-0.817 (0.045)	-0.010 (0.001)	-0.253 (0.016)	-0.036 (0.001)	-0.164 (0.011)
FF	-0.002 (0.001)	-0.155 (0.100)	-0.014 (0.001)	-0.601 (0.044)	-0.253 (0.001)	-0.698 (0.022)	-0.056 (0.001)	-0.014 (0.001)
DM	0.006 (0.001)	-1.703 (0.159)	0.018 (0.001)	-1.813 (0.069)	0.006 (0.001)	-0.127 (0.001)	0.031 (0.001)	-1.000 (0.008)
IL	-0.007 (0.001)	-0.333 (0.120)	-0.029 (0.001)	-0.434 (0.040)	-0.049 (0.001)	-0.232 (0.014)	-0.108 (0.001)	-0.229 (0.005)
DG	0.005 (0.001)	-1.965 (0.114)	0.015 (0.001)	-2.321 (0.070)	0.031 (0.001)	-2.389 (0.051)	0.022 (0.001)	-1.407 (0.009)
SF	0.013 (0.002)	-2.095 (0.232)	0.043 (0.002)	-2.449 (0.084)	0.084 (0.001)	-2.422 (0.034)	0.139 (0.001)	-2.138 (0.018)
JY	0.004 (0.001)	-0.197 (0.104)	0.011 (0.001)	-0.615 (0.449)	0.026 (0.001)	-0.733 (0.029)	0.094 (0.001)	-1.892 (0.013)

Notes: Numbers in parentheses are standard errors
N = number of observations
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-5
Cross-Currency Tests: GMM Estimation

	Null Hypothesis		
	$b_i=b_j$	$b_i=1.0$	$b_i=0.0$
Maturity	$X^2(8)$	$X^2(9)$	$X^2(9)$
1 month N=659	336 (0.00)	1192 (0.00)	473 (0.00)
3 month N=650	1881 (0.00)	10609 (0.00)	3586 (0.00)
6 month N=637	8781 (0.00)	656101 (0.00)	13991 (0.00)
12 month N=558	52730 (0.00)	23825809 (0.00)	77304 (0.00)

Notes: Numbers in parentheses are marginal significance levels
N = number of observation.

Table 2-6
Test of H_0: $b_1-b_2 = 1-2b_2 \leq 0$
(Cross-Currency Estimation)

Panel A: SUR Estimation

Maturity

	1 month N=165	3 month N=50	6 month N=25	12 month N=11
CD	3.53 (0.00)	0.33 (0.37)	0.13 (0.45)	-0.19 (0.57)
BP	2.98 (0.00)	3.41 (0.00)	2.65 (0.01)	0.93 (0.19)
BF	5.54 (0.00)	2.41 (0.01)	0.89 (0.19)	5.06 (0.00)
FF	0.97 (0.16)	-0.48 (0.68)	0.60 (0.28)	5.27 (0.00)
DM	4.96 (0.00)	1.78 (0.04)	1.34 (0.09)	7.33 (0.00)
IL	4.04 (0.00)	2.07 (0.02)	0.44 (0.33)	1.66 (0.06)
DG	6.12 (0.00)	5.06 (0.00)	3.42 (0.00)	5.62 (0.00)
SF	3.70 (0.00)	3.02 (0.00)	3.13 (0.01)	6.34 (0.00)
JY	2.43 (0.01)	2.12 (0.02)	1.14 (0.13)	4.41 (0.00)

Panel B: GMM Estimation

Maturity

	1 month N=659	3 month N=650	6 month N=637	12 month N=558
CD	7.66 (0.00)	6.97 (0.00)	0.42 (0.34)	-41.20 (1.00)
BP	8.17 (0.00)	24.36 (0.00)	70.89 (0.00)	106.70 (0.00)
BF	13.74 (0.00)	29.20 (0.00)	46.99 (0.00)	62.73 (0.00)
FF	6.67 (0.00)	25.21 (0.00)	53.41 (0.00)	2046.24 (0.00)
DM	13.82 (0.00)	33.32 (0.00)	426.16 (0.00)	182.31 (0.00)
IL	6.97 (0.00)	23.14 (0.00)	54.21 (0.00)	158.96 (0.00)
DG	21.53 (0.00)	40.20 (0.00)	56.18 (0.00)	224.09 (0.00)
SF	11.20 (0.00)	35.13 (0.00)	85.77 (0.00)	143.63 (0.00)
JY	6.70 (0.00)	22.95 (0.00)	43.18 (0.00)	180.60 (0.00)

Notes: Test statistics are t-statistics
Numbers in parentheses are marginal significance levels
N = Number of observations
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-7
GMM Single Equation Residuals' Correlation Coefficients
(Cross-Maturity)

Canadian dollar

	3-month	6-month	12-month
1-month	0.484	0.407	0.353
3-month		0.703	0.533
6-month			0.689

British pound

	3-month	6-month	12-month
1-month	0.580	0.425	0.304
3-month		0.742	0.538
6-month			0.766

Belgian franc

	3-month	6-month	12-month
1-month	0.581	0.428	0.301
3-month		0.761	0.542
6-month			0.758

French franc

	3-month	6-month	12-month
1-month	0.571	0.439	0.288
3-month		0.770	0.544
6-month			0.769

Deutsche mark

	3-month	6-month	12-month
1-month	0.577	0.395	0.247
3-month		0.722	0.487
6-month			0.721

Italian lira

	3-month	6-month	12-month
1-month	0.577	0.407	0.262
3-month		0.730	0.510
6-month			0.744

Dutch guilder

	3-month	6-month	12-month
1-month	0.569	0.377	0.205
3-month		0.718	0.438
6-month			0.698

Swiss franc

	3-month	6-month	12-month
1-month	0.583	0.392	0.204
3-month		0.723	0.422
6-month			0.676

Japanese yen

	3-month	6-month	12-month
1-month	0.523	0.413	0.177
3-month		0.722	0.366
6-month			0.636

Table 2-8
Cross-Maturity Estimation: GMM
(N=558)

Maturity

	1 month		3 month		6 month		12 month	
	a	b	a	b	a	b	a	b
CD	-0.004	-1.368	-0.008	-0.364	-0.014	0.103	-0.022	0.809
	(0.001)	(0.357)	(0.001)	(0.480)	(0.003)	(0.441)	(0.005)	(0.294)
BP	-0.006	-1.473	-0.018	-1.380	-0.036	-1.238	-0.059	-0.451
	(0.002)	(0.413)	(0.007)	(0.404)	(0.013)	(0.427)	(0.025)	(0.497)
BF	-0.003	-0.848	-0.007	-0.316	-0.009	0.200	-0.010	0.154
	(0.002)	(0.279)	(0.006)	(0.394)	(0.011)	(0.538)	(0.020)	(0.585)
FF	-0.004	-0.027	-0.013	-0.333	-0.025	-0.321	-0.044	-0.020
	(0.002)	(0.101)	(0.007)	(0.170)	(0.013)	(0.239)	(0.024)	(0.014)
DM	0.004	-1.787	0.008	-1.174	-0.003	-0.095	0.031	-0.909
	(0.001)	(0.404)	(0.003)	(0.300)	(0.005)	(0.008)	(0.018)	(0.417)
IL	-0.011	-0.444	-0.033	-0.447	-0.058	-0.310	-0.109	-0.2892
	(0.002)	(0.207)	(0.007)	(0.228)	(0.013)	(0.199)	(0.021)	(0.184)
DG	0.003	-2.530	0.009	-2.427	0.017	-2.333	0.026	-1.815
	(0.001)	(0.474)	(0.004)	(0.520)	(0.001)	(0.536)	(0.017)	(0.399)
SF	0.012	-2.214	0.026	-1.662	0.043	-1.494	0.096	-1.717
	(0.004)	(0.554)	(0.014)	(0.630)	(0.031)	(0.728)	(0.065)	(0.805)
JY	0.005	-1.097	0.017	-1.379	0.037	-1.434	0.082	-1.509
	(0.002)	(0.364)	(0.006)	(0.389)	(0.012)	(0.430)	(0.028)	(0.571)

Notes: Numbers in parentheses are standard errors
N = Number of observations
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-9
Cross-Maturity Tests: GMM Estimation
(N = 558)

Null Hypothesis

	$b_i = b_j$ $\chi^2(3)$	$b_i = 1.0$ $\chi^2(4)$	$b_i = 0.0$ $\chi^2(4)$
CD	70.53 (0.00)	90.72 (0.00)	70.87 (0.00)
BP	5.69 (0.13)	40.50 (0.00)	14.63 (0.01)
BF	7.89 (0.05)	95.01 (0.00)	33.00 (0.00)
FF	8.91 (0.03)	5625.20 (0.00)	10.21 (0.04)
DM	42.56 (0.00)	22243.70 (0.00)	193.58 (0.00)
IL	2.65 (0.45)	127.89 (0.00)	11.43 (0.02)
DG	1.94 (0.59)	108.18 (0.00)	49.41 (0.00)
SF	3.16 (0.37)	52.70 (0.00)	27.56 (0.00)
JY	2.05 (0.56)	38.69 (0.00)	12.63 (0.01)

Notes: Test statistics are chi-square-statistics
Numbers in parentheses are marginal significance levels
Number of observations = 558
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

Table 2-10
Test of H_0: $b_1 - b_2 = 1 - 2b_2 \leq 0$
(Cross-Maturity Estimation)

	Maturity			
	1 month	3 month	6 month	12 month
CD	5.23 (0.00)	1.80 (0.04)	0.90 (0.18)	-1.05 (0.84)
BP	4.78 (0.00)	4.66 (0.00)	4.07 (0.00)	1.91 (0.03)
BF	4.84 (0.00)	2.07 (0.02)	0.56 (0.39)	0.59 (0.38)
FF	5.21 (0.00)	4.89 (0.00)	3.34 (0.00)	36.64 (0.00)
DM	5.67 (0.00)	5.62 (0.00)	74.40 (0.00)	3.38 (0.00)
IL	4.56 (0.00)	4.14 (0.00)	4.07 (0.00)	4.28 (0.00)
DG	6.39 (0.00)	5.63 (0.00)	5.28 (0.00)	5.81 (0.00)
SF	4.90 (0.00)	3.43 (0.00)	2.74 (0.00)	2.75 (0.01)
JY	4.39 (0.00)	4.83 (0.00)	4.50 (0.00)	3.52 (0.01)

Notes: Test statistics are t-statistics
Numbers in parentheses are marginal significance levels
Number of observations = 558
CD = Canadian dollar
BP = British pound
BF = Belgian franc
FF = French franc
DM = Deutsche mark
IL = Italian lira
DG = Dutch guilder
SF = Swiss franc
JY = Japanese yen.

A Latent Variable Model

Model Specification

The joint GMM tests across currency and across maturity confirm the existence of time-varying risk premiums in the forward exchange market. In this section we investigate the possibility that risk premiums in the forward exchange rates move together in proportion to a single latent variable.

In the finance literature the risk return trade-off has been characterized with a single beta model. The riskiness of any asset is measured by the covariation of the excess return on the asset with the excess return from some benchmark portfolio.

(26) $E_t(R_{t+k,k} - R^z_{t+k,k}) = \beta_t \; E_t(R^b_{t+k,k} - R^z_{t+k,k}),$

where $E_t(.)$ is an expectation operator conditioned on an information set I_t, $R_{t+k,k}$ is the k-period return on an asset purchased at t, and where $\beta_t = cov(R_{t+k,k}, R^b_{t+k,k})/var(R^b_{t+k,k})$.

The same asset pricing relationship can be derived from a more general framework of the Intertemporal Asset Pricing Model (ICAPM).[7] The ICAPM of Merton (1973) and Lucas (1978, 1982) impose some testable restrictions on asset pricing. In discrete time framework with a representative investor with time separable utility function defined over consumption c, the behavior of the excess returns must satisfy the following first-order condition.

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[7]There are conceptual advantages in using ICAPM. As pointed out by Roll (1977), the econometric content of static CAPM is valid only if the benchmark return $R^b_{t+k,k}$ lies on the conditional mean-variance frontier. However, ICAPM does not have the implication that the return on the aggregate wealth portfolio be mean-variance efficient and it is not required that observations on a benchmark return for a single beta model be available a priori.

(27) $E_t[Q_{t,t+k}\ (1+h_t(i))] = 1$,

where $1+h_t(i)$ is dollar price of the consumption good at t, and

$$Q_{t,t+k} = \frac{\delta\ U'(c_{t+n})\ P_t}{U'(c_t)\ P_{t+n}}$$

is the marginal rate of substitution of dollars between t and t+k and δ is a discount factor.

Then using risk premiums (26) can be rewritten as

(28) $E_t[r_t(i)] = \beta_{it}\ E_t[r_t(b)]$, where

$\beta_{it} = cov_t[r_t(i),\ r_t(b)]/var_t[r_t(b)]$.

Thus, the expected dollar excess return on asset i is proportional to the expected excess return on a benchmark portfolio whose payoff is conditionally correlated with the intertemporal marginal rate of substitution of dollar. As with most empirical CAPM, we assume that conditional betas are constant.[8]

For the empirical representation of (28), we define risk premium of exchange rate i as

$y^i_{t+k} = \log(F^i_{t,k} - S^i_{t+k})$,

where $F^i_{t,k}$ is the k-period forward rate observed at t and S^i_{t+k} is the spot exchange rate observed at t+k. All exchange rates are measured by the dollar prices of foreign currencies. Since the expected excess return on the benchmark portfolio is unobservable, the expected excess return on the benchmark portfolio is treated as a latent variable and the information variables observed at t are substituted. In this study, Euro-interest rate differentials are used as information variables.

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[8]It should be noted that, as pointed out by Hansen and Hodrick (1983), such tests are not tests of a fully specified general equilibrium model, but are tests of proportional co-movement of expected excess returns which are motivated by the ICAPM.

Then the 7-equation system of latent variable model is

(29) $y_{1t} = \alpha_0 + \alpha_1 x_{it} + \alpha_2 x_{2t} + \dots + \alpha_7 x_{7t} + e_{1t},$

$y_{it} = \beta_i\alpha_0 + \beta_i\alpha_1 x_{it} + \beta_i\alpha_2 x_{2t} + \dots + \beta_i\alpha_7 x_{7t} + e_{it},\ i=2,\dots,7.$

In a compact form,

(30) $Y_t = \Gamma X_t + E_t,$

where Y_t is a 7-dimensional vector of risk premiums, X_t is a vector of information variables including a constant, E_t is a 7-dimensional vector of forecast errors which are orthogonal to X_t, and Γ is a 7X8 matrix of regression coefficients.

The model (29) imposes non-linear restrictions of a single latent variable structure, $\tau_{ij} = \beta_i\alpha_j$, on (30). β_1 is normalized to unity so the first row of Γ estimates the α coefficients, the first column estimates the other β coefficients, and the lower right-hand block diagonal matrix is restricted. Thus, there are 42 restrictions which force risk premiums to move together in proportion with one another.

The equation system (30) is estimated by the GMM. The GMM estimation is based on 56 (7 equations by 8 information variables) orthogonality conditions. More precisely, the first-order conditions of the GMM sets 14 (number of coefficients) linear combinations of the 56 orthogonality restrictions equal to zero. Thus there are 42 linearly independent combinations that are not necessarily equal to zero but which should be close to zero under the specified restrictions. Estimation without restrictions, which is identical to the usual GMM estimation, is equivalent to setting 56 sample orthogonality conditions equal to zero. A test of specified non-linear restrictions is conducted by examining the minimized value of the objective function. A theoretical value of objective function is zero without restrictions.

Hence, the value of the minimized objective function, which is the difference between the values of the objective functions with and without restrictions, serves as a test statistic. Hansen (1982) demonstrated that $Tg_T(b)'W_Tg_T(b)$ is asymptotically chi-square distributed with 42 (56-14) degrees of freedoms, where $g_T(b)$ is a minimized value of (13), W_T is an estimator of an optimal weighting matrix, and T is the number of observations.

Each α coefficient measures the impact of each information variable on the asset's risk premium and each β coefficient represents the riskiness of each asset relative to the asset whose β is normalized to one.

Empirical Results

Among seven risk premiums (the British pound, the Canadian dollar, the Deutsche mark, the French franc, the Dutch guilder, the Swiss franc, and the Japanese yen), the Deutsche mark (DM) is chosen as a benchmark risk premiums whose β is set to one.[9]

Table 2-11 reports the cross-currency latent variable estimation for three different maturities. For one-month maturity, the restrictions of latent variable model is rejected. However, for three- and six-month maturities, the single latent variable model is not rejected. Even though almost all individual coefficients are

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[9]In an original Harris data, 9 exchange rates for 4 different maturities (one-, three-, six, and twelve-month) forward exchange rates and Euro-interest rates are available. Due to frequent missing observations in the Belgian franc and the Italian lira, only seven exchange rates are included in this study. Also, frequent missing values in twelve-month Euro-interest rates forces us to drop twelve-month maturity in our study.

Table 2-11
Latent Variable Estimates
(Cross-Currency Estimation)

Panel A: Maturity = 1 month
Number of observations = 547

$X^2(42)$ = 86.45   P=0.00

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0006	0.0009	(0.23)
β_1	1.0000			α_1	-2.6496	0.7059	(0.00)
β_2	3.0875	0.8105	(0.00)	α_2	-0.1984	0.1881	(0.15)
β_3	0.9883	0.1770	(0.00)	α_3	-0.0339	0.0352	(0.17)
β_4	-0.1031	0.1300	(0.21)	α_4	-0.0337	0.1820	(0.43)
β_5	2.8080	0.4493	(0.00)	α_5	2.6481	0.6762	(0.00)
β_6	1.2048	0.2259	(0.00)	α_6	0.3874	0.1870	(0.02)
β_7	0.9104	0.2109	(0.00)	α_7	0.2100	0.1356	(0.06)

Panel B: Maturity = 3 month
Number of observations = 538

$X^2(42)$ = 41.18   P=0.51

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0042	0.0024	(0.04)
β_1	1.0000			α_1	-2.1747	0.3912	(0.00)
β_2	0.6335	0.1554	(0.00)	α_2	-0.3889	0.0881	(0.00)
β_3	0.6322	0.0556	(0.00)	α_3	-0.1212	0.0495	(0.01)
β_4	0.4304	0.0855	(0.00)	α_4	0.4123	0.1991	(0.02)
β_5	-0.0391	0.1091	(0.36)	α_5	0.2806	0.0521	(0.00)
β_6	1.4867	0.1037	(0.07)	α_6	1.9687	0.2734	(0.00)
β_7	-1.5896	0.4218	(0.00)	α_7	-0.1986	0.1136	(0.04)

Panel C: Maturity = 6 month
Number of observations = 525

$X^2(42)$ = 20.70   P=0.99

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0021	0.0009	(0.01)
β_1	1.0000			α_1	-0.2570	0.1800	(0.01)
β_2	5.1984	0.7387	(0.00)	α_2	0.5337	0.0898	(0.00)
β_3	2.0700	0.2027	(0.00)	α_3	0.0727	0.0219	(0.00)
β_4	-0.8932	0.1363	(0.00)	α_4	-0.5575	0.0940	(0.00)
β_5	1.8536	0.1481	(0.00)	α_5	0.1251	0.0432	(0.00)
β_6	0.1598	0.1626	(0.16)	α_6	-0.0548	0.0388	(0.08)
β_7	5.4786	0.7884	(0.00)	α_7	0.0606	0.0269	(0.01)

Table 2-11(Continued)
Latent Variable Estimates
(Cross-Currency Estimation)

Notes: Coeff. = Estimates of coefficients
SE = Standard errors of estimates
P = Marginal significance levels
β_1 = β of Deutsche mark
β_2 = β of British pound
β_3 = β of French franc
β_4 = β of Canadian dollar
β_5 = β of Dutch guilder
β_6 = β of Swiss franc
β_7 = β of Japanese Yen
α_1 = Euro interest rate differential (US-DM)
α_2 = Euro interest rate differential (US-BP)
α_3 = Euro interest rate differential (US-FF)
α_4 = Euro interest rate differential (US-CD)
α_5 = Euro interest rate differential (US-DG)
α_6 = Euro interest rate differential (US-SF)
α_7 = Euro interest rate differential (US-JY).

Table 2-12
Latent Variable Estimates
(Cross-Maturity Estimation)

Canadian dollar

$X^2(6) = 10.05$ P=0.12

	Coeff.	SE	P		Coeff.	SE	P
				α_0	0.0021	0.0008	(0.01)
β_1	1.0000			α_1	1.8142	1.1526	(0.06)
β_2	1.8091	0.4390	(0.00)	α_2	-0.2028	0.6770	(0.38)
β_3	2.3661	0.9352	(0.00)	α_3	0.1760	0.2792	(0.26)

British pound

$X^2(6) = 9.26$ P=0.16

	Coeff.	SE	P		Coeff.	SE	P
				α_0	0.0036	0.0002	(0.07)
β_1	1.0000			α_1	2.5157	2.3404	(0.14)
β_2	1.3416	0.6496	(0.02)	α_2	2.5424	1.6981	(0.07)
β_3	0.0807	1.9910	(0.48)	α_3	-0.7175	0.9691	(0.04)

French franc

$X^2(6) = 2.18$ P=0.90

	Coeff.	SE	P		Coeff.	SE	P
				α_0	0.0002	0.0006	(0.37)
β_1	1.0000			α_1	0.0205	0.0945	(0.41)
β_2	-10.9235	37.58	(0.39)	α_2	0.0682	0.2053	(0.37)
β_3	-23.0495	74.67	(0.38)	α_3	-0.0244	0.0753	(0.37)

Deutsche mark

$X^2(6) = 6.66$ P=0.35

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0124	0.0050	(0.01)
β_1	1.0000			α_1	-0.3439	2.3368	(0.44)
β_2	3.3777	0.7351	(0.00)	α_2	-2.9813	1.9258	(0.06)
β_3	5.7475	1.7423	(0.00)	α_3	2.0875	0.9137	(0.01)

Dutch guilder

$X^2(6) = 6.63$ P=0.36

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0103	0.0033	(0.00)
β_1	1.0000			α_1	0.0568	1.1240	(0.48)
β_2	2.9691	0.2834	(0.00)	α_2	-0.0153	0.0116	(0.10)
β_3	4.9218	0.6821	(0.00)	α_3	0.8456	0.2744	(0.00)

Table 2-12(Continued)
Latent Variable Estimates
(Cross-Maturity Estimation)

Swiss franc

$X^2(6) = 8.81$ P=0.18

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0067	0.0036	(0.03)
β_1	1.0000			α_1	14.5014	4.3985	(0.00)
β_2	-0.0459	0.5376	(0.47)	α_2	-6.4454	2.1329	(0.00)
β_3	-0.3081	0.8770	(0.36)	α_3	1.0048	0.6614	(0.06)

Japanese yen

$X^2(6) = 6.03$ P=0.42

	Coeff.	SE	P		Coeff.	SE	P
				α_0	-0.0129	0.0037	(0.00)
β_1	1.0000			α_1	-0.2985	1.9659	(0.44)
β_2	3.2397	0.3084	(0.00)	α_2	-0.1931	0.9352	(0.42)
β_3	6.5373	0.9852	(0.00)	α_3	0.7583	0.3854	(0.02)

Notes: Coeff. = Estimates of coefficients
SE = Standard errors of estimates
P = Marginal significance levels
β_1 = β of 1-month risk premium
β_2 = β of 3-month risk premium
β_3 = β of 6-month risk premium
α_1 = 1-month forward premium
α_2 = 3-month forward premium
α_3 = 6-month forward premium
Number of observation = 525.

significant for three- and six-month maturities, risk characteristics of foreign exchange rates are not persistent across maturities. In other words, the cross-currency estimation fails to reveal any systematic currency-specific risk characteristics.

Table 2-12 reports the cross-maturity joint estimation of single latent variable model for each exchange rate. As with the previous cross-maturity estimations, the longest lags of six-month forward rate (moving average of 26 lags) is used in the GMM implementation. All seven equation systems are not rejected. Individual betas of four exchange rates (the Canadian dollar, the Deutsche mark, the Dutch guilder, and the Japanese yen) are significant and they show that betas of longer maturity is larger than those of short maturity. Cross-maturity test results are consistent with our intuition and reveal maturity-specific risk characteristics of foreign exchange rates.

Conclusions

This study documents a rejection of the hypothesis that forward foreign exchange rates are unbiased predictors of future spot rates. The cross-maturity tests and the cross-currency tests for longer term maturities are possible by exploiting nonoverlapping weekly data using the GMM procedure. The rejection of unbiasedness hypothesis is consistent with various maturities and exchange rates. Joint tests across currency and across maturity also confirm not only the existence of time-varying risk premiums in the forward foreign exchange market but that the variations in the forward premiums rather than movements in expected spot exchange rate changes account for most of the volatility in forward exchange rates. We also found that the resolution of

uncertainty in the foreign exchange market is not uniform across maturity and there is maturity-specific information investors can use in their investment decisions.

The existence of time-varying risk premiums in the forward foreign exchange market is extended into the framework of the single latent variable model to test whether the risk premiums in the forward exchange markets move in proportion to a single latent variable. The single latent variable can be interpreted as a constant beta on a single, unobservable benchmark portfolio in the context of the Intertemporal Capital Asset Pricing Model (ICAPM).

The non-linear restrictions imposed by the single latent variable model are not rejected only for the three- and six-month maturity cross-currency estimation. We cannot identify any systematic currency-specific risk characteristics. However, for the cross-maturity estimation, the single latent variable model is not rejected for all seven currencies. Furthermore, all significant betas of longer maturity risk premiums (three- and six-month) are larger than those of short maturity risk premiums (one-month).

CHAPTER III
THE REACTION OF SPOT AND FORWARD FOREIGN EXCHANGE MARKETS TO MONEY SUPPLY ANNOUNCEMENTS

Introduction

The impact of money supply growth on the nominal interest rates has been one of the most active research topics in Financial Economics. The response of interest rates to a monetary variable is of interest to investors, academicians, and the monetary authority. Lately, the impact of weekly money supply announcements on changes in nominal interest rates has attracted numerous studies (Cornell (1983a, 1983b), Cornell and French (1986), Falk and Orazem (1985), Frankel and Hardouvelis (1985), Girton and Nattress (1985), Grossmam (1981), Loeys (1985), Roley and Walsh (1985), Siegel (1985), Urich and Wachtel (1981), and Urich (1982)).

Money supply announcements are hypothesized to affect nominal interest rates through the following three channels. First, associated with the Keynesian macro-economic theory, an increase in money growth leads to a decrease in interest rates through a liquidity effect. Second, unexpected growth in money may lead market participants to expect the monetary authority to counteract such growth in the future by tightening money supply. Therefore, there may be a policy anticipation effect which leads to higher interest rates in anticipation of future liquidity effect. Third, associated with the monetarists' view, nominal interest rates may rise in response to a higher money growth through the Fisher effect. The market interprets an unexpected growth of money as

an indication that the Fed has raised its target money growth rate and accordingly revises inflationary expectations upward which in turn drives up nominal interest rates. Since the pure policy anticipation effect is equivalent to a change in real interest rate through the contraction of money supply, it is also called the real interest rate hypothesis. Since there is time lag between the Fed's actual open market operations and the announcement of money supply, the liquidity effect, which is short term in nature, is not likely to be observed with new announcement. Consequently, research emphasis has been given to two competing hypotheses: the policy anticipation (real interest rates) hypothesis and the inflationary expectations hypothesis.

The evidence obtained shows that increases in unanticipated money supply persistently lead to increases in nominal interest rates. Given the Fisher relationship linking nominal interest rate to expected real interest rate and expected inflation rate, the explanation of the observed effect could only be due to the two sources. The expected real rate effect suggests that the monetary authorities dislike unexpected increases in money supply, and intend to reverse the unanticipated increase in the future with the result that real rates are anticipated to increase. This, of course, assumes that the Federal Reserve is able to achieve its objectives. On the other hand, if the Fed is unable or unwilling to counteract the unexpected increase, the increase in nominal interest rates could be attributed to an expected increase in future inflation.

Unfortunately, studies utilizing fixed-income securities have been unable to discern adequately the two alternative explanations of the effect of unanticipated money supply announcements on nominal interest

rates. For example, Urich and Wachtel (1981) claimed that immediate response of most recently issued 90-day Treasury bill yield is supportive of real interest rate hypothesis. On the other hand, Cornell (1983 a) found significantly positive responses for long-term yields which is consistent with inflation expectation hypothesis.

A consequence of this is an analysis of the foreign exchange markets in search of a more unambiguous answer (Cornell (1982), Engel and Frankel (1984), Hakkio and Pearce (1985), Hardouvelis (1985), Husted and Kitchens (1985), and Roley (1987)). The results indicate that spot exchange rates of the U.S. dollar appreciate in response to unanticipated increases in money supply. When this result is coupled with the finding of an associated increase in nominal interest rates, the evidence is consistent with the expected real interest rate transmission process.

By focusing only on the spot exchange markets, the analysis of the impact on the foreign exchange rates is at best incomplete. The advantage in yield differential between the domestic and foreign countries in favor of dollar denominated securities induced by unexpected increases in money supply leads to forward rate adjustments in addition to spot rate appreciations. Since, the issue of whether unexpected money supply announcements convey information about expected real rates or expected inflation rates is still controversial and by no means unambiguous, further empirical tests are of interest. Joint examination of the spot and the forward exchange markets of different maturities makes it feasible to test additional testable restrictions not previously examined. For example, even though a finding of spot dollar appreciation is supportive of the "anticipated liquidity effect"

proposition, the possibility that the effect may have been overemphasized is statistically analyzed. This possibility is due to the fact that spot rates have the characteristics of financial markets and therefore respond rapidly to changes in expectations of future market fundamentals. They may, however, overreact to compensate for the slow adjustment in the commodity markets to unexpected shocks along lines suggested by Dornbusch (1976) and Frankel (1979). In particular, the increase in inflation associated with positive money supply innovations are not expected to take effect until sometime in the future. In short, because of the differential adjustment speeds in the commodity and financial markets, the real rate effect may dominate in the very short run and the expected inflation rate effect may slowly increase in importance over time.

The purpose of this chapter is to provide a more integrated and comprehensive study of the foreign exchange rate effects of unexpected movements in money supply. This is achieved by systematically and rigorously exploring the relationships between money supply innovations and spot exchange rates, forward exchange rates, and the interaction between the spot and forward rates.

Hypotheses

The arbitrage condition known as interest rate parity theory plays an important role in modern theories of exchange rate determination. It stipulates that in the absence of transaction costs, forward premiums are exactly offset by differentially denominated bonds of similar risks:

(1) $f_{n,t} - s_t = r_t - r_t^*$,

where fn,t = the natural logarithm of the n-period forward exchange rate of foreign currency in terms of the U.S. dollar observed at time t,

s_t = the natural logarithm of the spot exchange rate of foreign currency in terms of the U.S. dollar observed at time t,

r_t = the yield on an n-period U.S. dollar denominated discount bond,

r_t^* = the yield on a bond that is similar in all respects to r_t except that it is denominated in foreign currency.

The forward premium is then defined as $f_{n,t} - s_t$. If (1) does not hold, an investor can realize riskless profits either by borrowing in the U.S., converting the dollars to foreign currency at the spot rate, investing the proceeds at the foreign interest rate, and covering the foreign investment at the forward exchange rate or by executing the reverse transactions for the dollar and the foreign currency.

It is important to emphasize that since (1) is an arbitrage condition, it is consistent with wide variety of equilibrium theories of international asset pricing with risk averse investors. Empirically, the equality between the foreign exchange rates and the money market instruments specified by (1) is strongly supported by, for example, Frankel and Levich (1975, 1981), Marston (1976), and McCormick (1979).

Condition (1) can be used to identify the various relationship between the spot and the forward exchange rates. In deriving new testable restrictions, it is important to ensure that the empirical regularity conditions already established in the extant literature are not violated. Two such conditions can be identified. First, the literature on the reaction of nominal interest rates to unexpected money

supply changes found that nominal interest rate (r_t) increases in response to unexpected increase in the money supply. Second, the prevailing evidence on the spot exchange reaction to weekly money supply announcements indicates that spot dollar appreciates for positive money supply surprises.

Since daily data are used, we can safely assume that there are no systematic adjustments in the prices of foreign currency denominated bonds around the announcement dates. When this assumption is coupled with the first regularity condition, we obtain the implication that the forward premium for the foreign currency should increase in response to an unexpected increase in money supply. This may be hypothesized as

H1 : $(f'_{n,t}-s'_t)-(f_{n,t}-s_t) = (f'_{n,t}-f_{n,t})-(s'_t-s_t) > 0$,

where $f'_{n,t}$ and s'_t are post-announcement quotes and $f_{n,t}$ and s_t are pre-announcement quotes. Therefore, in light of the second regularity condition, for H1 to be consistent with sample data, forward rate may either increase or decrease. The next two hypotheses are concerned with these two possibilities of the forward exchange rate behavior.

When spot dollar appreciates in reaction to unexpected increases in money supply, the results are supportive of the proposition that increases in nominal interest rate (r_t) are induced by increases in expected real interest rate. Spot dollar appreciations associated with capital inflows into dollar denominated securities, however, are also associated with forward dollar depreciations as investors simultaneously hedge their dollar investment by buying foreign currencies forward. This hypothesis may be summarized as

H2 : $(s'_t-s_t) < 0$

$(f'_{n,t}-f_{n,t}) > 0.$

Of course, for H1 to be supported, it must also be true that $(s_t^{\prime}-s_t) < (f_{n,t}^{\prime}-f_{n,t})$.

As suggested by H2, according to interest rate parity, forward dollar should depreciate when monetary surprises are positive. That they instead appreciate indicates that they do so to prevent arbitrage possibilities when spot exchange rate overshoots. The latter situation arises when one considers, in addition to (1), the goods market with its slower speed of price adjustment. Consider the following incorporation of the goods market:

(2) $s_t-s_t^{*} = c[(I_t-I_t^{*})-(f_{n,t}-s_t)]$,

where s_t^{*} = equilibrium spot exchange rate at time t,

I_t = expectation at time t of U.S. inflation rate from time t to t+n,

I_t^{*} = expectation at time t of foreign inflation rate from time t to t+n.

The constant term c > 0 captures the speed of adjustment and the inflation rates capture the price variations in the commodity markets. It should be emphasized that no assumptions contrary to market efficiency are invoked in specifying that spot exchange rate is in disequilibrium ($c \neq 0$). When (1) is combined with (2), the model maintains that when real interest rates are equalized across countries, current spot exchange rate is an equilibrium rate ($s_t = s_t^{*}$) and no overshooting of spot exchange rates occurs. However, under the present assumption that no systematic adjustments in foreign currency denominated interest rate (r_t^{*}) occurs around money supply announcement dates, overshooting is a distinctive possibility.

Then the hypothesis of differential price adjustments can be stated as follows:

H3 : $(s_t^{\prime}-s_t) < 0$

$(f_{n,t}^{\prime}-f_{n,t}) < 0$ and

$(s_t^{\prime}-s_t) < (f_{n,t}^{\prime}-f_{n,t})$.

Data and Empirical Results

Data

The money supply data used is the one compiled by the Money Market Service Inc. since September 1977. This produces the median expected money supply of major market participants and is used to compute the unanticipated weekly money supply which is defined as the logarithm of actual minus the logarithm of expected money supply. The survey covers a cross-section of 50 to 60 market participants and is conducted on Tuesday for the money supply to be announced later in the week. The announcement now takes place on Thursday afternoon, around 4 p.m., but announced monetary aggregate and the date of the announcement have changed through time.[1]

The exchange rate is defined as the U.S. dollars per unit of foreign currency. The foreign exchange data is obtained from the International Monetary Market Yearbooks. The spot and forward exchange

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[1] In February 1980, the Fed changed its announced monetary aggregate from M1 to M1B. The reason for this change was to incorporate the growing importance of other checkable deposits at all depository institutions. M1A is defined as the old M1 (currency plus demand deposits at commercial banks) excluding demand deposits held by foreign banks and official institutions. M1B is equal to M1A plus NOW account, ATS, credit union share drafts, and the demand deposits at mutual savings banks. On the same day, the Fed changed its announcement date from Thursday to Friday afternoon. In January 1982, the Fed started to report M1 again. Then in January 1984, the Fed switched back to Thursday announcement.

rate data consists of interbank daily bid quotes observed at 1 p.m. for 5 major currencies; the British pound, the Canadian dollar (CD), the Deutsche mark (DM), the Swiss franc (SF), and the Japanese yen (JY). The response of exchange rates to an unanticipated weekly money supply is measured by the logarithm of change from the pre-announcement quotes (1 p.m. bid quotes on announcement day) to the post-announcement quotes (1 p.m. bid quotes on the next business day) for the spot and forward contracts of 5 different maturities (1,2,3,6, and 12 months). Hence, for the Thursday announcement period, exchange rate changes are measured from Thursday to Friday and for the Friday announcement period they are calculated from Friday to Monday. Other things being equal, longer measurement interval implies more chances of noise and it is expected that the result from Thursday announcement period shows more significant relationship if there is any. The sample period extends from October 1979 to December 1985. The starting date chosen coincides with the change in the operating procedure of the Federal Reserve from a money targeting procedure to an interest rate stabilization procedure. Cornell (1982) and Urich and Wachtel (1981) have shown that the interest rates responded more significantly to the unanticipated weekly money supply after the Fed's operating procedure change. Two sub-samples from the entire sample are also examined. They cover the periods from October 1979 to September 1982 and from October 1982 to December 1985. October 1982 is used as a split as the Federal Reserve switched back to an interest rate stabilization procedure in that month. Thus, the 2 sub-samples cover two separate monetary policy regimes. A priori, we would expect to observe stronger effect of unanticipated money supply on

the exchange rates when the monetary authorities target money supplies rather than interest rates.

Summary Statistics

Table 3-1 reports summary statistics for the unanticipated money supply. The average median forecasting errors reported by the Money Market Service Inc. is less than 0.04% of actual weekly money supply in dollar terms. The number of incidence for the increase and decrease in unanticipated money supplies is almost equal for each period.[2]

We can also compare across sample periods. The first sub-sample period (October 1979 - September 1982) is a monetary aggregate target period and shows higher mean error and more variations. To test whether two sub-samples are drawn from the same distribution, the Kolmogorov-Smirnov test is used. The marginal significance level for the Kolmogorov-Smirnov test is 0.31 and the null hypothesis that two sub-samples are drawn from the same distribution is not rejected. The forecast error process seems to be independent of the Fed's policy. In a sense, it is consistent with the rational expectations assumption since different monetary policy implications have been already discounted in the market participants' forecasting process.

Regression Tests

The foreign exchange rates response to the unanticipated money supply change is estimated by the following regression equations:

(3) $y_{ijt} = b_{0ij} + b_{1ij}\, MS_t + e_{ijt}$,

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[2]It is worth minding that, since these statistics are calculated from medians of forecast errors, we cannot infer population distributions of forecast errors from Table 3-1.

where y_{ijt} is in turn spot exchange rate changes ($DS_t = s_t' - s_t$), forward exchange rate changes ($DF_t = f_{n,t}' - f_{n,t}$), and forward premium changes ($DFP_t = (f_{n,t}' - s_t') - (f_{n,t} - s_t)$) for 5 different maturities ($j=1,..,5$) and for 5 currencies ($i=1,..,5$). However, not all equations are independent. The regression coefficients for the forward rate changes are the sum of coefficients for the spot rate changes and for the forward premium changes.

Table 3-2, 3-3, and 3-4 show the announcement effect on exchange rates for the whole and two subsample periods. As previously mentioned, the two subsample periods are distinguished by the Fed's operating procedure. The first sample period is characterized as the money target period and the second sample period is described as the interest rate stabilization period.

The results for the whole sample period are supportive of hypothesis H1. All coefficients for the spot exchange rate changes are negative (spot dollar appreciation) and coefficients for the British pound, the Deutsche mark, the Swiss franc, and the Japanese yen are significant at 10% level. Forward market responses support H3 instead of H2 as all significant coefficients except one show U.S. dollar appreciation in the forward market. All significant coefficients for forward premium have positive signs (increase in the forward premiums). This implies that both spot and forward exchange rates appreciate but spot appreciation dominates over forward appreciation and as a result forward premium increases.

A clear pattern emerges from the comparison of the results for two subsample periods. For the monetary target period (Table 3-3), all five currencies show significant responses in the forward market even though

the British pound and the Japanese yen lost their significance in the spot market. In contrast, the interest stabilization period (Table 3-4) shows no significant responses either in the spot or in the forward markets.

In addition to single equation test, we also perform joint market tests since testing of individual coefficient does not provide the appropriate joint test that all $b_j=0$. An appropriate joint test takes into account the correlation among foreign exchange forward rates of different maturities. Even though individual regression coefficients are the same for both tests, joint test provides more efficient test statistics for the test of joint market response across different maturities. The F-tests are constructed by the cross-equation restrictions that all coefficients for forward rate changes and forward premium changes are zero for each currency. Table 3-5 reports the joint tests results. In the whole sample period, U.S. dollar appreciates significantly in all forward markets except the British pound. Forward premiums for U.S. dollar are also highly significant for the British pound, the Canadian dollar, and the Japanese yen.

The sample period or monetary policy dependent results can be seen more distinctively by the joint tests. During money target period, U.S. dollar appreciates and forward premiums increase in all the forward markets significantly. In contrast, during the interest rate stabilization period sample, even though their signs are supportive of H3, they reveal no significant responses. These results are not surprising since the participants in the exchange market would be more sensitive to the unanticipated money supply when the Fed itself is also more concerned about the monetary aggregate. In the first sample period

Table 3-1
Summary Statistics for Unanticipated Changes in the Money Stock

Sample Period : October 1979 - December 1985

VARIABLES	OBS	MEAN	STD	SKEWNESS
MS	314	0.000383	0.004414	0.727
MSP	163	0.003625	0.003344	2.060
MSN	151	-0.003057	0.002301	-0.690

Sample Period : October 1979 - September 1982

VARIABLES	OBS	MEAN	STD	SKEWNESS
MS	154	0.000487	0.005292	0.680
MSP	77	0.004512	0.003978	1.942
MSN	77	-0.003535	0.002785	-0.769

Sample Period : October 1982 - December 1985

VARIABLES	OBS	MEAN	STD	SKEWNESS
MS	160	0.000277	0.003535	0.252
MSP	86	0.002856	0.002390	1.039
MSN	74	-0.002720	0.001906	-0.571

Notes: OBS = Number of Observations
STD = Standard Deviation
MS = Unexpected Change in the Money Stock
MSP = Unexpected Increase in the Money Stock
MSN = Unexpected Decrease in the Money Stock.

Table 3-2
Estimates of Announcement Effect on Foreign Exchange Rates

Sample Period : October 1979 - December 1985

	BP	CD	DM	SF	JY
DS	-0.181	-0.045	-0.338	-0.409	-0.306
	(0.08)	(0.18)	(0.01)	(0.00)	(0.08)
DF1	-0.139	0.111	-0.307	-0.367	-0.270
	(0.37)	(0.23)	(0.01)	(0.00)	(0.01)
DF2	-0.101	-0.022	-0.315	-0.338	-0.203
	(0.33)	(0.48)	(0.01)	(0.00)	(0.04)
DF3	-0.142	-0.003	-0.334	-0.354	-0.195
	(0.20)	(0.93)	(0.01)	(0.00)	(0.05)
DF6	-0.061	0.037	-0.400	-0.323	-0.214
	(0.55)	(0.27)	(0.22)	(0.02)	(0.27)
F12	-0.075	0.066	-0.233	-0.173	-0.111
	(0.50)	(0.09)	(0.05)	(0.21)	(0.31)
DFP1	0.042	0.156	0.031	0.042	0.036
	(0.73)	(0.07)	(0.80)	(0.60)	(0.81)
DFP2	0.071	0.022	0.023	0.071	0.102
	(0.13)	(0.11)	(0.84)	(0.34)	(0.49)
DFP3	0.039	0.042	0.005	0.055	0.110
	(0.45)	(0.00)	(0.97)	(0.48)	(0.47)
DFP6	0.120	0.082	-0.062	0.086	0.091
	(0.00)	(0.00)	(0.85)	(0.44)	(0.68)
DFP12	0.106	0.111	0.105	0.236	0.195
	(0.04)	(0.00)	(0.40)	(0.03)	(0.22)

Notes: DS = Change in the spot exchange rate
DFi = Change in the i month forward rate
DFPi = Change in the i month forward premium
BP = British pound
CD = Canadian dollar
DM = Deutsche mark
SF = Swiss franc
JY = Japanese yen
Numbers in parentheses are marginal significance levels.

Table 3-3
Estimates of Announcement Effect on Foreign Exchange Rates

Sample Period : October 1979 - September 1982

	BP	CD	DM	SF	JY
DS	-0.172	-0.054	-0.369	-0.449	-0.353
	(0.17)	(0.25)	(0.01)	(0.03)	(0.23)
DF1	-0.118	-0.038	-0.277	-0.388	-0.277
	(0.37)	(0.38)	(0.04)	(0.02)	(0.04)
DF2	-0.103	-0.035	-0.305	-0.392	-0.216
	(0.38)	(0.43)	(0.02)	(0.01)	(0.12)
DF3	-0.074	-0.009	-0.301	-0.384	-0.215
	(0.53)	(0.82)	(0.02)	(0.02)	(0.12)
DF6	-0.018	0.036	-0.382	-0.272	-0.112
	(0.87)	(0.41)	(0.48)	(0.14)	(0.43)
DF12	-0.039	0.072	-0.169	-0.230	-0.154
	(0.76)	(0.19)	(0.17)	(0.14)	(0.30)
DFP1	0.054	0.017	0.091	0.061	0.075
	(0.46)	(0.40)	(0.18)	(0.63)	(0.77)
DFP2	0.069	0.020	0.064	0.057	0.136
	(0.00)	(0.39)	(0.32)	(0.65)	(0.60)
DFP3	0.098	0.045	0.067	0.065	0.137
	(0.00)	(0.05)	(0.29)	(0.62)	(0.60)
DFP6	0.153	0.091	-0.013	0.178	0.241
	(0.00)	(0.00)	(0.98)	(0.30)	(0.37)
DFP12	0.133	0.127	0.200	0.219	0.199
	(0.10)	(0.01)	(0.00)	(0.11)	(0.46)

Note: DS = Change in the spot exchange rate
DFi = Change in the i month forward rate
DFPi = Change in the i month forward premium
BP = British pound
CD = Canadian dollar
DM = Deutsche mark
SF = Swiss franc
JY = Japanese yen
Numbers in parentheses are marginal significance levels.

Table 3-4
Estimates of Announcement Effect on Foreign Exchange Rates

Sample Period : October 1982 - December 1985

	BP	CD	DM	SF	JY
DS	-0.193	-0.020	-0.256	-0.307	-0.211
	(0.31)	(0.22)	(0.32)	(0.09)	(0.13)
DF1	-0.191	0.427	-0.355	-0.317	-0.252
	(0.57)	(0.04)	(0.12)	(0.09)	(0.09)
DF2	-0.112	-0.007	-0.323	-0.215	-0.174
	(0.61)	(0.87)	(0.16)	(0.23)	(0.21)
DF3	-0.282	-0.017	-0.380	-0.279	-0.151
	(0.19)	(0.72)	(0.10)	(0.15)	(0.31)
DF6	-0.142	0.045	-0.448	-0.411	-0.428
	(0.47)	(0.40)	(0.07)	(0.07)	(0.32)
DF12	-0.144	0.063	-0.353	-0.031	-0.020
	(0.47)	(0.26)	(0.14)	(0.90)	(0.90)
DFP1	0.002	0.447	-0.100	-0.010	-0.041
	(0.99)	(0.03)	(0.72)	(0.90)	(0.34)
DFP2	0.080	0.027	-0.068	0.091	0.036
	(0.47)	(0.02)	(0.66)	(0.65)	(0.39)
DFP3	-0.089	0.037	-0.124	0.028	0.060
	(0.47)	(0.02)	(0.66)	(0.65)	(0.39)
DFP6	0.051	0.064	-0.193	-0.105	-0.217
	(0.27)	(0.01)	(0.50)	(0.43)	(0.59)
DFP12	0.049	0.082	-0.097	0.275	0.190
	(0.40)	(0.01)	(0.74)	(0.15)	(0.07)

Note: DS = Change in the spot exchange rate
DFi = Change in the i month forward rate
DFPi = Change in the i month forward premium
BP = British pound
CD = Canadian dollar
DM = Deutsche mark
SF = Swiss franc
JY = Japanese yen
Numbers in parentheses are marginal significance levels.

Table 3-5
Joint Tests for the Announcement Effect on
Foreign Exchange Forward Rates and Forward Premiums

Sample Period : October 1979 - December 1985

	BP	CD	DM	SF	JY
DF	0.732 (0.60)	5.061 (0.00)	2.180 (0.05)	2.748 (0.02)	3.140 (0.00)
DFP	3.800 (0.00)	5.377 (0.00)	0.932 (0.46)	1.200 (0.31)	2.487 (0.03)

Sample Period : October 1979 - September 1982

	BP	CD	DM	SF	JY
DF	2.190 (0.05)	2.931 (0.01)	2.950 (0.01)	2.980 (0.01)	3.140 (0.00)
DFP	4.622 (0.00)	3.082 (0.01)	2.595 (0.02)	2.205 (0.05)	2.918 (0.01)

Sample Period : October 1982 - December 1985

	BP	CD	DM	SF	JY
DF	0.432 (0.83)	2.325 (0.04)	0.878 (0.50)	1.147 (0.33)	1.426 (0.21)
DFP	0.468 (0.80)	2.290 (0.04)	0.382 (0.86)	1.469 (0.19)	1.685 (0.13)

Notes: Numbers in parentheses are marginal significance levels
F-Statistics are for H_0 : $b_i=0$ for all i.

of the money target policy, monetary disturbances are expected to be offset by the Fed's immediate policy actions which in turn bring about interest rate changes. In the second sample period of the interest rate stabilization policy, interest rate movements are closely monitored on a daily basis by the Fed and the monetary shock should not have as much impact as in the previous case.

During most of the first sample period, announcements were made on Friday so that exchange rate changes were measured between Friday and Monday. On the other hand, the exchange rate changes were calculated from Thursday to Friday for most of the second sample period. Given the fact that longer measurement interval involves relatively frequent intrusions of extraneous events, the results are much more significant under the money target period. Studies of Urich and Wachtel (1981) and Cornell (1982) also found that after the Fed's change in operating procedure on October 6, 1979, the correlation between unanticipated money supply change and nominal interest rate change increased significantly. However, their sample periods were confined to pre-1982 data.[3]

Nonparametric Test

The effect of an unanticipated change in money on the foreign exchange markets has been investigated by a linear regression model. The use of standard regression analysis implicitly imposes two

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[3]Another reason for the small effect prior to October 1979 can be found in the development in the financial market. In addition to the change in the monetary policy emphasis, introduction of new instruments in the banking system such as automatic transfer between demand and time deposits made the clear definition of money difficult. To take account of this innovation, the Fed changed its announced monetary aggregate in February 1980 from M1 to M1B.

restrictions: a specific model and for inferences, normally distributed residuals. This formulation assumes that the dependent variables are linearly related to the unanticipated change in the money stock. Casual observation shows that there are some occasions when the market either did not respond at all or respond in a direction opposite that hypothesized by the theory. In this case, the standard estimates of the market's response to unanticipated money supply changes may be biased due to an assumption of constant proportional response. In addition to linearity, there is a more prominent reason for the concern about specification error. Take the case of unanticipated money supply effect on forward premiums. By taking expectations on both sides of regression equation (3), ex ante changes in forward premium is a constant. This means that, under the rational expectations or efficient market hypothesis, forward premium is a random walk process with a constant drift. However, in the interest rate parity relationship (1), ex ante changes in forward premium is an interest rate differential between countries. There is no a priori reason for the constant interest rate differentials. Furthermore, it is well known that interest rate differentials among countries are mainly determined by real economic activities and also by economic policies of each country which are dynamic by nature and can never be a constant. Standard linear regression model, therefore, is in direct conflict with interest rate parity. Despite apparent doubt about standard model, our limited tractability forces us to use the standard model.

A natural alternative to linear regression analysis is a nonparametric test. Nonparametric test assumes neither normality nor

model specification. However, the magnitude of changes are not taken into account and hence the degree of responsiveness cannot be measured.

A nonparametric test is adapted from a statistical procedure recently developed by Merton (1981) and Henriksson and Merton (1981) (hereafter referred to as HM). The HM test is developed for testing market-timing forecasting ability in a portfolio management setting. The HM test procedure is briefly summarized. Most terms involved have been altered to fit our tests.

Consider the predictability of the sign of weekly money supply forecast error, without regarding the magnitude, for the upcoming movement in the exchange market. To put it another way, the question is how reliably we can predict the increase or decrease in the exchange rates by just knowing the direction of unanticipated money supply change.[4]

Let $S(t')$ be the change in the spot rate around the announcement which is observed after public announcement of weekly money supply at time t'. Let $M(t)$ be the forecast error for the weekly money supply (unanticipated money supply change) available at t, where $t<t'$. Then define the following conditional probabilities.

(5) $P_1(t') = \text{Prob}[M(t)>0 \mid S(t')<0]$

(6) $P_2(t') = \text{Prob}[M(t)<0 \mid S(t')>0]$

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[4]The question may not sound practical since the asset prices are assumed to be adjusted immediately after receiving new information and the market does not know the sign of forecast error until the Fed's announcement. Since announced money supply is actually a lagged measure and the survey precedes the announcement by two or three days, at least the Fed knows the forecast errors before the market responds. However, since we are only concerned about the direction of changes, it has no implication to the profit opportunity by the insiders in the Fed.

$P_1(t')$ is the conditional probability of a correct prediction given that $S(t')<0$, and $P_2(t')$ is the conditional probability of a correct prediction given that $S(t')>0$.[5] It is assumed that $P_1(t')$ and $P_2(t')$ do not depend upon the magnitude of $S(t')$. Hence, the conditional probability of a correct prediction depends only on whether or not $S(t')>0$.

Merton (1981) shows that a necessary and sufficient condition for the forecast error to have no predictive power is

(7) $P_1(t')+P_2(t') = 1.$

The nonparametric test of HM takes advantage of the fact that the conditional probabilities of a correct prediction can be used to measure predictability, yet they do not depend on the distribution of exchange rate changes. A test of a null hypothesis that the forecast error has no predictive power for the upcoming movements in the exchange market can be accomplished by testing (7), where $P_1(t')$ and $P_2(t')$ are not known. We want to determine the probability that a given outcome from our sample came from a population that satisfies our null hypothesis.

HM show that under the null hypothesis, the probability distribution for n_1, the number of correct predictions given that $S(t')<0$, has the form of a hypergeometric distribution:

(8) $$P(n_1 | N_1, N, n) = \frac{\binom{N_1}{n_1}\binom{N_2}{n-n_1}}{\binom{N}{n}}$$

where n_1 = number of correct predictions, given $S(t')<0$,

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[5]To avoid the confusion, the term "forecast error" is reserved for the weekly money surprises (unanticipated change in the money stock). The term "prediction" is used for the HM test.

n = number of times where $M(t)>0$,

N_1 = number of observations where $S(t')<0$,

N_2 = number of observations where $S(t')>0$,

$N = N_1 + N_2$ = total number of observations.

Given N_1, N_2 and n, the distribution of n_1 under the null hypothesis is determined by equation (10) where the feasible range for n_1 is given by

(9) $\underline{n}_1 = \max(0,n-N_2) < n_1 < \min(N_1,n) = \bar{n}_1$

Then, confidence intervals for testing the hypothesis of no forecasting ability can be obtained by (8) and (9). For one-tail test with a confidence level of c, one would reject the null hypothesis if $n_1>x^*(c)$ where $x^*(c)$ is defined as the solution to

(10) $$\frac{\sum_{x=x^*}^{n_1} \binom{N_1}{x} \binom{N_2}{n-x}}{\binom{N}{n}} = 1-c$$

For large sample, the hypergeometric distribution can be approximated by the normal distribution. The parameters used for this normal approximation are the mean and the variance for the hypergeometric distribution given in (8).

Since the normal approximation conditions are not satisfied, hypergeometric distribution is used for the estimation of critical value of $x^*(c)$ for three different confidence levels of c.[6] For the spot exchange rate changes (DS), a negative relationship to the money

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[6]Henriksson and Merton show that the normal distribution can be an excellent approximation for determining the confidence interval for the hypergeometric distribution when N_1 is approximately equal to N_2 and n is approximately one half of N. Except for the British pound, the number of cases where spot exchanges rate increases is large relative to the opposite cases, which violates the first condition. Despite the approximation conditions are not met, normal approximation results are very similar to the results from the hypergeometric distribution.

Table 3-6
Nonparametric Test

Sample Period: October 1979 - December 1985

	BP	CD	DM	SF	JY
S		**	**	*	***
F1		**	*	*	***
F2		*	**	*	***
F3			**		**
F6			**		**
F12			*		**
P1	*		***	***	**
P2	***	**	***	***	***
P3	***	**	***	***	***
P6	***	***	***	***	***
P12	***	***	***	***	***

Sample Period: October 1979- September 1982

	BP	CD	DM	SF	JY
S		*	***	*	**
F1		**	**	*	***
F2			***	*	***
F3			***		**
F6			**		*
F12			*		**
P1	*	*	***	***	**
P2	***	**	***	***	***
P3	***	***	***	***	***
P6	***	***	***	***	***
P12	***	***	***	***	

Sample Period: October 1982 - December 1985

	BP	CD	DM	SF	JY
S		*			**
F1		*			**
F2					**
F3		*			**
F6					*
F12					
P1			**	***	
P2	*		**	**	**
P3				**	**
P6					**
P12			*	**	***

Notes: *** denotes significant at 0.01 level
** denotes significant at 0.05 level
* denotes significant at 0.10 level.

surprise is hypothesized for the estimation of test statistics. For the forward premium changes (DFPi), a positive relationship is assumed. Nonparametric test is as a whole supportive of H1. Even though the spot market responses are not as decisive as the forward market, the spot and forward markets adjust jointly as H1 suggests. Especially, the forward premium increase after unanticipated rise in money supply is consistent with the F-tests in regression analysis. Furthermore, the effect of stated monetary policy on the qualitative relationship between money surprises and exchange market response can be captured more vividly by nonparametric test. Considering the relatively small sample size of money target period, which has 154 observations compared to 165 observation of interest rate smoothing period, the effect of the monetary authorities' stance on the market behavior is significant.

Further Tests

Thus far no economic distinction has been made between positive and negative unanticipated money supply changes. However, market participants may react differently depending on the direction of surprises. For example, if the Federal Reserve's main policy objective is to control inflation by maintaining target money supply, it would be more concerned about positive surprises. Under this scenario, the market may be more responsive to positive money supply shock. Another possible scenario for the asymmetric response is that during severe recessions the Fed may be forced into loosening its monetary policy to accommodate the economy. In this case, the market may be more responsive to negative money supply innovations. However, the same argument holds for the inflationary expectations hypothesis. Some institutional factors, like downward price rigidity, may render positive

surprises more important. Thus, the examination of asymmetric response to positive and negative money shock is of interest.

The following switching regression model is estimated for the possibility of asymmetric response of market participants to the positive and negative money supply surprises.

(11) $y_{it} = b_{0i} + b_{1i}\ MSP_t + b_{2i}\ MSN_t + e_{it}$,

where MSP = MS for positive shock

= 0 otherwise

MSN = MS for negative shock

= 0 otherwise.

The estimation for two separate subsamples of positive and negative shocks show the evidence of sample clustering in each side. In the subsample estimations, few coefficients are significant. It may be due to the loss of sample and the increased standard error in each subsample. Despite marginal gains of efficiency over the subsample estimation, the switching regression estimation for the spot exchange rate changes in Table 3-7 show no evidence of asymmetric affect. The estimated coefficients from original regressions are added in the first column for comparison purpose. F-tests for the null hypothesis of equal response to the positive and negative money surprises,

$$H_0 : b_{1i} = b_{2i}$$

cannot be rejected for all currencies. Our result is inconsistent with previous study of Grossman (1981), who found that positive money surprises had a larger impact on interest rates than negative surprises. However, direct comparison is difficult since two results are obtained from different market and also from different sample period.

Table 3-7
Estimates of Switching Regressions for Spot Exchange Rates

Sample Period: October 1979 - December 1985

	b	b_1	b_2	F-Statistics
BP	-0.181	-0.133	-0.251	0.126
	(0.08)	(0.44)	(0.26)	(0.72)
CD	-0.045	-0.059	-0.023	0.113
	(0.18)	(0.27)	(0.75)	(0.74)
DM	-0.338	-0.367	-0.297	0.028
	(0.01)	(0.09)	(0.29)	(0.87)
SF	-0.409	-0.271	-0.613	0.630
	(0.00)	(0.22)	(0.04)	(0.43)
JY	-0.306	-0.436	-0.117	0.330
	(0.08)	(0.13)	(0.75)	(0.57)

Sample Period: October 1979 - September 1982

	b	b_1	b_2	F-Statistics
BP	-0.172	-0.001	-0.436	1.178
	(0.17)	(0.99)	(0.11)	(0.28)
CD	-0.054	-0.072	-0.025	0.095
	(0.25)	(0.34)	(0.82)	(0.76)
DM	-0.369	-0.123	-0.747	1.949
	(0.01)	(0.58)	(0.01)	(0.16)
SF	-0.449	-0.169	-0.890	1.270
	(0.03)	(0.59)	(0.04)	(0.26)
JY	-0.353	-0.570	-0.018	0.346
	(0.23)	(0.23)	(0.98)	(0.56)

Sample Period: October 1982 - December 1985

	b	b_1	b_2	F-Statistics
BP	-0.193	-0.356	-0.009	0.266
	(0.31)	(0.32)	(0.98)	(0.61)
CD	-0.020	0.047	-0.105	0.967
	(0.22)	(0.57)	(0.29)	(0.33)
DM	-0.256	-0.720	0.332	1.535
	(0.32)	(0.11)	(0.54)	(0.22)
SF	-0.307	-0.271	-0.352	0.018
	(0.09)	(0.40)	(0.35)	(0.89)
JY	-0.211	-0.018	-0.470	0.115
	(0.13)	(0.98)	(0.60)	(0.74)

Notes: The first column is from Table 3-2 for comparison purposes
Numbers in parentheses are marginal significance levels
F-Statistics are for H_0: $b_1 = b_2$.

Conclusions

The effect of unanticipated changes in the money supply on the foreign exchange rates is examined under very general framework of interest rate parity. By examining jointly the spot and the forward exchange markets of different maturities, we can identify testable restrictions which should be held in equilibrium. Based on the empirical evidence that the spot exchange rates appreciations and forward premiums increase occurs simultaneously after unanticipated increase in the money supply, we provide convincing evidence that the complete chain of equilibrium process in the foreign exchange market is consistent with the hypothesis suggested by the interest rate parity theory and the real interest rate theory of money supply announcement effect. The evidence obtained in this Chapter is supported not only by the usual parametric tests but also by a nonparametric test which does not depend on any particular model specification and assumption on distribution.

Investors in the foreign exchange market do not show any asymmetric response to the unexpected increase and decrease in the money supply. We also find that the Fed's stated monetary policy significantly affects the market participants' reactions to the unanticipated money supply changes.

CHAPTER IV
RISK PREMIUMS IN THE U.S. TREASURY BILL SPOT AND FUTURES MARKETS

Introduction

Since the introduction of futures trading in three-month Treasury bills in 1976 on the Chicago Mercantile Exchange (CME), yields on Treasury bill futures contracts have been examined to understand the market expectations of the future course of interest rates. Like the forward interest rates implicit in the term structure of interest rates, the yields on the futures contracts also embody information about market expectations of future interest rates. Yields on Treasury bill futures contracts (futures rates) are essentially counterparts to the implied forward rates. They differ in that the futures rates are market rates observed from trading in the futures exchange and the implicit forward rates are estimated from the term structure of interest rates. Of course, institutional constraints between the two also exist. To the extent that the futures rates and forward rates represent yields to the same type of loan contract, any profitable trading opportunity will be exploited by arbitrage between the spot and futures markets. The existence of profitable arbitrage opportunities or inefficiencies in the Treasury bill futures market is therefore an important issue for investigators.

Several authors tested the efficiency of the Treasury bill futures market, but they found conflicting evidence. Lang and Rasche (1978), and Puglisi (1978) found the futures market to be inefficient. Poole

(1978) found that the differences between forward and futures yields are close enough to prevent profitable arbitrage. In a more extensive study by Rendleman and Carabini (1979), they suggest that many quasi-arbitrage opportunities have existed in the Treasury bill futures market.[1]

Regarding the revealed yield differentials between the futures rates and the implied forward rates, they have been attributed to market imperfections and institutional constraints such as taxes, transaction costs (arbitrage costs), margins, marking to market, differential risk premiums, and market segmentation. Cox, Ingersoll, and Ross (1981) derived a model in which forward and futures prices need not be equal with stochastic interest rates. Despite numerous studies the Treasury bill forward and futures yield differential has not been explained satisfactorily since none of the explanatory variables are readily observable.[2]

The first objective of this chapter is to examine the market segmentation hypothesis for the forward and futures yield differential. The regular event of weekly money supply announcements by the Federal Reserve provides a unique opportunity to test the segmentation hypothesis. To the extent that institutional constraints in the

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[1]Arbitrage or pure arbitrage refers to shorting securities or portfolio to fund a position in an economically equivalent securities or portfolio at a lower price. Quasi-arbitrage refers to selling securities from an existing portfolio to fund an economically equivalent position at a lower price.

[2]For the tax related literature, see Arak(1983), Cornell(1981), Kahl(1985), and Cornell and Reinganum(1981). As to the effect of margins in the futures market, see Kahl, Rutz, and Sinquefield (1985). Kane (1980) suggested market incompleteness as a source of yield differentials. For the development of literature to the market segmentation hypothesis, see Kane (1980) and Chow and Brophy (1982).

Treasury bill spot and futures markets remain constant or do not change significantly overnight around the announcements, any changes in the yield differentials between the two markets should be attributed to the market segmentation. Under market segmentation, traders in the two markets are distinct non-overlapping groups and they may form future interest rate expectations differently or may attach different risk premiums to the same monetary events. A natural hypothesis is that the Treasury bill futures, as a derivative contract of the spot bills, would respond to the monetary innovation as the spot bill does unless the two markets are governed by two distinctive investor groups.

The second objective is to examine the effect of weekly money supply announcements on the Treasury bill dealers' premium revealed in the bid-ask spread.

Forward-Futures Yield Spreads

Arbitrage Condition in the Treasury Bill Markets

Treasury bills are auctioned each business Monday for delivery on the Thursday of the same week. Bills that mature in 91 days and 182 days are auctioned every week, and 52-weeks bills are auctioned monthly, with minimum denominations of \$10,000, and with increment above this minimum of \$5,000. Prices are quoted in discount yields, both in bid and asked.

The Treasury bill futures contract, traded by the International Monetary Market (IMM) of the Chicago Mercantile Exchange (CME), calls for the delivery of spot bills having a face value of \$1 million and a time to maturity of 90 days at the expiration of the futures contract.

The quotes on the Treasury bill futures contracts are made according to the IMM-Index value.

IMM Index = 100.00% - Discount Yield.

This method of price quotation was adopted to insure that the bid price would be lower than the asked price, the usual relationship prevailing in most markets. The contracts trade for delivery in March, June, September, and December.[3] Delivery can be made on three business days beginning with the day of issue of 13-week Treasury bills in that month. Effective June 1983, futures contracts, delivery can be made on three successive business days. The first delivery day is on the first day of the spot month on which 13 week Treasury bill is issued and a one-year Treasury bill has 13 weeks remaining to maturity. The purpose of this change in the delivery process is to increase the supply of deliverable spot bills. As a consequence, deliverable bills are available earlier after this change and our sample from later period has more dense observations than in earlier period. Futures trading terminates on the business day immediately preceding the first delivery day.

The exposition is considerably simplified if continuously compounded annual rate of returns are employed rather than the discount rates quoted by dealers and the financial press. To estimate the forward and futures yields let us define the following notations.

(1) $s(t)$ = spot asked discount rate with t days remaining to maturity.

(2) $s(t+91)$ = spot asked discount rate with t+91 days remaining to maturity.

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[3]Effective July 2, 1980, a new quarterly cycle consisting of January, April, July, and October was listed for trading as regular contract months. However, trading activity for new contract cycle is negligible and contracts of the new cycle are ignored in this study.

(3) $f(t)$ = futures discount rate with t days remaining to maturity.

= 100 - IMM Index.

For each futures contract considered, two particular spot quotes are required to estimate the corresponding forward rate. The "short-term bill" denoted by $s(t)$ has its maturity date coinciding with the maturity date of the futures contract. According to the specification of the Treasury bill futures contracts, the "long-term bill" denoted by $s(t+91)$ is the deliverable bill for the futures contract. Then following the conventional way of using 360 days for a year, the spot and futures prices are calculated as

(4) $S(t) = 100 - (t/360)s(t)$,

(5) $S(t+91) = 100 - ((t+91)/360)s(t+91)$, and

(6) $F(t) = 100 - (91/360)f(t)$.

The futures price is the price to be paid at delivery and should be differentiated from the value of the futures contract.

The implied forward rate for 91 days in t days is

(7) $r(t) = (365/91) \log(S(t)/S(t+1))$.

The futures rate maturing in t days is

(8) $R(t) = (365/91) \log(100/F(t))$.

Except for the arbitrage costs, profitable arbitrage opportunities will exist if the forward rates are not the same as the corresponding futures rates at any point in time.[4] If, for example, the futures rate is less than the forward rate, that is, $R(t) < r(t)$, the following

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[4]Arbitrage costs include brokerage commissions in the futures market, bid-ask spread in the spot market, and special cost for shorting spot bill. For details of each cost, see Capozza and Cornell (1979).

position will generate riskless profit at maturity date of "long-term bill".

Short a bill maturing in t days

Invest the proceeds to buy a bill maturing in t+91 days

Sell a futures contract maturing in t days.

The exact opposite position in the spot and futures markets will also generate sure profit when the futures rate is higher than the forward rate.

Data, Hypothesis, and Empirical Results

The data covers from December 1974 to August 1987 with 613 sample points. The spot bill quotes are obtained from the Daily Quote Sheets of the New York Federal Reserve. The spot quotes reported by the New York Federal Reserve represents actual trading which takes place approximately at 3:30 P.M., and they are gathered from the dealers by telephone call.

The futures quotes are obtained from the International Monetary Market (IMM) Yearbooks of the Chicago Mercantile Exchange (CME). The quotes on the futures contracts are settlement prices of the day.[5]

The pre-announcement quotes are close and settlement prices for the spot and futures, respectively, on the announcement day. The same quotes are collected as the post-announcement quotes on the next business day. The announcements take place at around 4:00 P.M. (for the

[5]The settlement price is the price at which contracts are settled at the close of trading for the day. The settlement price, typically, is the last trading price for the day, but it is not always so. When the trading is not active at the end of the day, the settlement committee meets to establish a settlement price which fairly indicates the value of the futures contract at the close of the trading. The margin requirements in the futures contracts depend on the change in settlement prices.

details about the weekly money supply announcements procedure, see Chapter III).

The pre-announcement quotes in the spot and futures markets reflect all arbitrage related costs and their best prediction for and effect of the upcoming announcements. If the two markets' expectation formations are the same and the arbitrage costs remain constant for a very short time period, as short as one day, then the forward-futures spread would not change significantly after the announcements.

The t-test is utilized to the subsamples of different characteristics to test the null hypothesis that the forward yield, futures yield, and the forward-futures yield differential are the same before and after the announcement.

Table 4-1 reports the summary statistics and the t-test results for the subsamples of distinctive monetary policies. During the whole sample period, when there are positive monetary surprises, that is, when the actual money supply is larger than the survey expectations, forward rate increases 5.5 basis points in annual rate and futures rate also increases almost 6 basis points. As a result, forward-futures spread change is negligible and insignificant.

The sample period is then partitioned into three distinctive monetary regimes. The first period (1977.12 - 1979.9) and the third period (1982.10 - 1986.9) were characterized as interest rate stabilization periods and interest rates were monitored by the Federal Reserve. The second subsample period (1979.10 - 1982.9) was a money target period and a stable supply of money was the Fed's prime policy target. With positive monetary shock, as anticipated, both the forward and the futures rates responded significantly only in the money target

period. Also, the magnitude of the response was larger than any other period. The results from the subsample of negative shock shows that both rates are responsive only in the third period. The first period shows opposite signs even though they are all insignificant. The wrong signs may be due to the trend of increasing interest rate in that period. Noting also that the third period was a decreasing interest rate period, the trend of interest rate movement is an important factor determining the market's reaction to monetary shocks. The market participants seem to follow the trend in the general economy in forming their expectations. In an increasing interest rate period, only unexpected increases do matter, and in a period of decreasing interest rate, only downside surprises matter.

Table 4-2 replicates Table 4-1 for subsamples of different maturities. There is no discernible effect of maturities on the market reaction when announced money supply is larger than the market expectation. For the negative monetary surprise, all signs of coefficients are negative and more coefficients are significant. However, no systematic response either in the forward or in the futures rates is observed. Only for the maturity of 60 to 90 days of short-term bill, which is equivalent to the maturity of 150 to 180 days for the long-term bill, both the forward and futures rates react significantly.

To measure the quantitative relationship between the forecasting errors for the money supply and the interest rate changes the OLS is applied to the following regression equation.

(9) $y_t = a_0 + a_1 ER_t + e_t$,

where y is the change in the forward rates (DFWD), change in the futures rates (DFUT), and change in the forward-futures yield spread

respectively. ER is a measure of unanticipated money supply and is defined by

ER = log (Actual Money Supply / Market Expectation of Money Supply).

Table 4-3 reports the OLS results. In all sample periods, futures rates reacts significantly but the forward rates respond only in the second and the third period. The regression test is consistent with the t-test in Table 4-1, the coefficients in the money target period are all significant and the magnitude of response is also large. This result reinforces previous evidence that the monetary policy is an important determinant of market reaction. To satisfy the market segmentation condition, not only should the forward and futures rates react significantly but the yield spread after announcement should be significantly different from zero. Only money target period estimates meet these conditions.

Panel B of Table 4-3 tests the possibility of asymmetric response with respect to the direction of surprise. For this purpose, the switching regression model is specified as follows.

(10) $y_t = b_0 + b_1\, PER_t + b_2\, NER_t + e_t$,

where y are the same variables defined in (9),

PER = ER if ER is positive,

= 0 otherwise,

NER = ER if ER is negative,

= 0 otherwise.

The switching regression results reveal more informative evidence about the interest rates reaction to the monetary surprises. First, monetary policy dependent reaction is more distinctive. Under the interest rate stabilization policy of the first and the third sample periods, only

unexpected increases in the money supply affect the forward and futures rates. On the contrary, under the money target period, the market only reacts to unexpected decreases in the money. Furthermore, response to the negative shock is so large that we can conclude that the positive relationship between the monetary surprise and interest rate changes shown in Panel A is a direct result of the decisive reaction to the negative shock. As is the case of the OLS test, only money target policy subsample satisfies the segmentation condition.

Table 4-4 replicates Table 4-3 for subsamples of different maturities. The short-term bills with 30 to 60 days remaining to the maturity satisfies the stipulated segmentation condition. However, this finding is not supported by the Switching Regression Test of Panel B of Table 4-4.

Table 4-1
Yield Spread for Monetary Shocks

Panel A: Positive Shock (Unexpected Increase in Money Supply)

	1977.12 -1986. 8 N=313	1977.12 -1979.9 N=34	1979.10 -1982. 9 N=78	1982.10 -1986. 8 N=201
DFWD				
MEAN	0.0554	0.0202	0.1788	0.0134
STD	0.2679	0.0975	0.4143	0.1909
T	3.66	1.21	3.81	1.00
	(0.00)	(0.24)	(0.00)	(0.32)
DFUT				
MEAN	0.0598	0.0486	0.1728	0.0178
STD	0.2071	0.1136	0.3116	0.1437
T	5.11	2.49	4.90	1.76
	(0.00)	(0.02)	(0.00)	(0.08)
DFFS				
MEAN	0.0044	0.0284	-0.0060	0.0044
STD	0.2100	0.1171	0.3219	0.1647
T	0.37	1.41	-0.17	0.38
	(0.71)	(0.19)	(0.87)	(0.71)

Panel B: Negative Shock (Unexpected Decrease in Money Supply)

	N=284	N=58	N=74	N=152
DFWD				
MEAN	-0.0611	0.0029	-0.1517	-0.0415
STD	0.2655	0.0856	0.4677	0.1327
T	-3.88	0.26	-2.79	-3.85
	(0.00)	(0.80)	(0.01)	(0.00)
DFUT				
MEAN	-0.0349	0.0051	-0.0473	-0.0442
STD	0.2304	0.1065	0.3909	0.1433
T	-2.55	0.37	-1.04	-3.80
	(0.01)	(0.72)	(0.30)	(0.01)
DFFS				
MEAN	0.0262	0.0022	0.1045	-0.0027
STD	0.2194	0.0971	0.3619	0.1387
T	2.02	0.17	2.48	-0.24
	(0.04)	(0.86)	(0.02)	(0.81)

Notes: DFWD = changes in forward rates
DFUT = changes in futures rates
DFFS = changes in forward-futures spread
= DFUT - DFWD
N = number of observations
STD = standard deviation
T = t-statistic
Numbers in parentheses are marginal significance levels.

Table 4-2
Yield Spread for Maturities

Panel A: Positive Shock (Unexpected Increase in Money Supply)

	t≤30 N=126	30<t≤60 N=130	60<t≤90 N=119	t>90 N=238
DFWD				
MEAN	-0.0109	0.0006	0.0113	-0.0121
STD	0.3172	0.3280	0.2764	0.2136
T	-0.39	0.02	0.45	-0.87
	(0.70)	(0.98)	(0.65)	(0.38)
DFUT				
MEAN	0.0107	0.0305	0.0204	-0.0000
STD	0.2285	0.2497	0.2331	0.2055
T	0.52	1.39	0.96	0.00
	(0.60)	(0.17)	(0.34)	(0.99)
DFFS				
MEAN	0.0216	0.0300	0.0091	0.0122
STD	0.2226	0.2337	0.2035	0.2050
T	1.09	1.46	0.49	0.91
	(0.28)	(0.15)	(0.63)	(0.36)

Panel B: Negative Shock (Unexpected Decrease in Money Supply)

	t≤30 N=53	30<t≤60 N=61	60<t≤90 N=70	t>90 N=100
DFWD				
MEAN	-0.1307	-0.0265	-0.0660	-0.0420
STD	0.3597	0.2360	0.2714	0.2115
T	-2.64	-0.88	-2.04	-1.98
	(0.01)	(0.38)	(0.05)	(0.05)
DFUT				
MEAN	-0.0488	-0.0148	-0.0570	-0.0243
STD	0.2568	0.2612	0.2143	0.2072
T	-1.38	-0.44	-2.22	-1.17
	(0.17)	(0.66)	(0.03)	(0.24)
DFFS				
MEAN	0.0818	0.0118	0.0091	0.0176
STD	0.2593	0.1457	0.2155	0.2345
T	2.30	0.63	0.35	0.75
	(0.03)	(0.53)	(0.73)	(0.45)

Notes: DFWD = changes in forward rates
DFUT = changes in futures rates
DFFS = changes in forward-futures spread
= DFUT - DFWD
t = number of days remaining to the maturity of short-term bill
N = number of observations
STD = standard deviation
T = t-statistic
Numbers in parentheses are marginal significance levels.

Table 4-3
Regression Tests

Panel A: OLS for the Monetary Policy Subsamples

	77.12 -86. 8 N=613	77.12 -79. 9 N=95	79.10 -82. 9 N=160	82.10 -86. 8 N=358
DFWD	a_1	a_1	a_1	a_1
	0.1819	0.0103	0.3618	0.1060
s	0.0250	0.0192	0.0651	0.0259
	(0.00)	(0.59)	(0.00)	(0.00)
DFUT				
	0.1545	0.0475	0.2476	0.1302
s	0.0204	0.0225	0.0534	0.0218
	(0.00)	(0.07)	(0.00)	(0.00)
DFFS				
	-0.0274	0.0372	-0.1141	0.0241
s	0.0203	0.0214	0.0506	0.0239
	(0.18)	(0.09)	(0.03)	(0.31)

Panel B: Switching Regression for the Monetary Policy Subsamples

	77.12 -86. 8 N=613		77.12 -79. 9 N=95		79.10 -82. 9 N=160		82.10 -86. 8 N=358	
DFWD	b_1	b_2	b_1	b_2	b_1	b_2	b_1	b_2
	0.196	0.165	0.010	-0.027	0.148	0.695	0.149	0.047
s	0.044	0.048	0.045	0.026	0.106	0.150	0.045	0.057
	(0.00)	(0.00)	(0.03)	(0.30)	(0.16)	(0.00)	(0.00)	(0.41)
DFUT								
	0.211	0.090	0.125	0.016	0.147	0.404	0.200	0.035
s	0.035	0.039	0.055	0.032	0.086	0.122	0.038	0.048
	(0.00)	(0.02)	(0.03)	(0.62)	(0.09)	(0.00)	(0.00)	(0.47)
DFFS								
	0.015	-0.075	0.023	0.043	-0.001	-0.291	0.051	-0.012
s	0.036	0.039	0.054	0.031	0.085	0.120	0.042	0.053
	(0.67)	(0.06)	(0.67)	(0.17)	(0.99)	(0.02)	(0.23)	(0.82)

Notes: DFWD = changes in forward rates
DFUT = changes in futures rates
DFFS = changes in forward-futures spread
= DFUT - DFWD
N = number of observations
s = standard error of estimates
Numbers in parentheses are marginal significance levels.

Table 4-4
Regression Tests

Panel A: OLS for the Subsamples by Maturity

	$t\le30$ $N=126$	$30<t\le60$ $N=130$	$60<t\le90$ $N=119$	$t>90$ $N=238$
	a_1	a_1	a_1	a_1
DFWD	0.1854	0.2080	0.1943	0.1495
s	0.0595	0.0626	0.0494	0.0367
	(0.02)	(0.00)	(0.00)	(0.00)
DFUT	0.1172	0.0174	0.1793	0.1484
s	0.0433	0.0472	0.0412	0.0352
	(0.01)	(0.00)	(0.00)	(0.00)
DFFS	-0.0682	-0.0337	-0.0150	-0.0011
s	0.0430	0.0464	0.0387	0.0364
	(0.12)	(0.00)	(0.70)	(0.98)

Panel B: Switching Regression for the Subsamples by Maturity

	$t\le30$ $N=126$		$30<t\le60$ $N=130$		$60<t\le90$ $N=119$		$t>90$ $N=238$	
	b_1	b_2	b_1	b_2	b_1	b_2	b_1	b_2
DFWD	0.311	0.099	0.314	0.039	0.180	0.308	-0.009	0.243
s	0.129	0.099	0.098	0.131	0.081	0.102	0.064	0.069
	(0.02)	(0.32)	(0.00)	(0.77)	(0.03)	(0.00)	(0.88)	(0.00)
DFUT	0.189	0.068	0.207	0.119	0.222	0.221	0.202	-0.003
s	0.094	0.072	0.074	0.099	0.068	0.085	0.063	0.069
	(0.05)	(0.34)	(0.01)	(0.23)	(0.00)	(0.01)	(0.00)	(0.97)
DFFS	-0.123	-0.031	-0.107	0.080	0.042	-0.087	0.211	-0.246
s	0.093	0.071	0.075	0.100	0.060	0.075	0.069	0.076
	(0.19)	(0.67)	(0.15)	(0.43)	(0.48)	(0.25)	(0.00)	(0.00)

Notes: DFWD = changes in forward rates
DFUT = changes in futures rates
DFFS = changes in forward-futures spread
= DFUT - DFWD
t = number of days remaining to the maturity of short-term bill
N = number of observations
s = standard error of estimates
Numbers in parentheses are marginal significance levels.

Money Supply Announcements and Bid-Ask Spreads

Price risk to the security dealers comes from either information asymmetry or increase in the information uncertainty. Price risk of information asymmetry is the case when dealers may suffer losses from information trading by the informed traders. Price risk from information uncertainty is the expected losses from the price fluctuation and possible plunge in inventory value.

The dealer is one who stands ready to buy or sell securities at the dealer's quoted bid and ask prices, respectively. To meet the demand of immediacy from customers, security dealers are obliged to assume an inventory of securities. The price risk is a component of dealer's holding cost and the expected losses from price risk are an increasing function of the degree of uncertainty. Jaffe and Winkler (1976), Copeland and Galai (1983), and Glosten and Milgrom (1985) show that at the time of increased uncertainty the dealer should widen the bid-ask spread (the dealer's source of revenue) to minimize the expected losses from the price risks.

To assess the information content of the weekly money supply announcements, define the following notations suppressing the time index:

(11) B = bid-ask spread in the pre-announcement close quotes.

(12) B' = bid-ask spread in the post-announcement close quotes.

(13) I = information set available before the announcement.

(14) I' = information set available after the announcement.

Bid-ask spreads in the pre-announcement close quotes, reflect the price risk given the information set I. If the announcement has any information content that the dealers can utilize in assessing the future

price uncertainty, then the old information set (I) is a subset of new information set (I') and the bid-ask spread in the post-announcement close quotes would be smaller than that of post-announcement close quotes.[6] On the other hand, announcement only reveals large and successive forecasting errors and adds uncertainty to the market, then bid-ask spread would increase reflecting increased price uncertainty.[7] Using defined notations,

(15) If $I \varepsilon I'$ then $B > B'$, and

If $I' \varepsilon I$ then $B < B'$, where ε is a notation for a subset.

The data sources and the sample data period are identical to the forward-futures spread study. The percentage bid-ask spread defined below is used for empirical purposes.

$$B = \frac{(\text{Ask Price} - \text{Bid Price})}{(\text{Ask Price} + \text{Bid Price})/2} \times 100.0 \tag{16}$$

The bid-ask spread depends on the bill maturity, the interest rate level, and the degree of information uncertainty. Longer maturity bill prices are lower than those of shorter maturity bills and hence to cover the fixed cost of operation the percentage bid-ask spread of long maturity bill is larger than short maturity bill's bid-ask spread. In

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[6]Most infrequent and irregular event announcements such as merger announcements and earnings or dividend announcements for individual firm reveals its information contents by themselves. However, regular event especially for the general economy such as money supply announcement, unemployment, and discount rate changes need to be analyzed and filtered to be used as a useful information in decision making.

[7]Actually dealers bid-ask spread policy depends on their attitude toward risk and utility function. Since we are focusing on the relative changes in the bid-ask spread not bid-ask spread itself, risk characteristic of security dealers is not our concern. Also, to assess the price risk properly, trading volume and turnover rate of existing inventory must be considered. However, data availability on trading volume in the Treasury bill market prohibits such extension.

the high interest rate period bill prices are low and the percentage bid-ask spread is also large relative to the low interest rate period. As shown in Table 4-5, the bid-ask spread of long maturity bill is approximately twice as large as that of short maturity bill. Also the bid-ask spread of high interest rate period of late seventies and early eighties (the second sample period in terms of monetary policy) is almost three times as large as the third sample period of relatively low and stable interest rates.

To examine the effect of money supply announcement on the bid-ask spread, t-test is used to examine the changes in the bid-ask spread for short and long-term bills. Also summary statistics for four bid-ask spreads (before and after announcement spreads for short and long maturity bills each) are reported in Table 4-5. As a whole, after the Federal Reserve's announcement, the percentage bid-ask spread decreases but the decrease is not significant either for the short or for the long maturity bills. The same test is applied to the three subsamples periods of distinct monetary policies. Average bid-ask spreads also decreases except for the long maturity bills in the first sample period. However, none of the bid-ask spread changes are significant.[8] Panel B reveals more informative result. The bid-ask spread declines regardless of the sign of the monetary shocks. However, after the market realizes that actual money supply is greater than the market's expectation, the bid-ask spread drops almost 10% for the short maturity bills

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[8]Bid-ask spread is regressed against the money supply forecasting error to examine the quantitative relationship between two variables. None of the coefficients are significant and hence they are not reported.

Table 4-5
Bid-Ask Spread of Spot Bills

Panel A: Whole Sample Period

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0247	0.0232	0.0456	0.0452	-0.0015	-0.0004
STD	0.0333	0.0282	0.0429	0.0436	0.0231	0.0170
MIN	0.0010	0.0010	0.0060	0.0060	-0.471	-0.078
MAX	0.477	0.326	0.487	0.484	0.211	0.176
T					-1.56	-0.62
					(0.12)	(0.54)

Panel B: Subsample by Monetary Policies

Sample Period: 77.12 - 79. 9

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0228	0.0235	0.0406	0.0402	0.0007	-0.0005
STD	0.0128	0.0141	0.0153	0.0189	0.0081	0.0131
MIN	0.002	0.010	0.0002	0.010	-0.031	-0.033
MAX	0.061	0.084	0.090	0.148	0.038	0.092
T					0.87	-0.34
					(0.39)	(0.73)

Sample Period: 79.10 - 82. 9

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0434	0.0422	0.0833	0.0824	-0.0013	-0.0009
STD	0.0458	0.0464	0.0668	0.0672	0.0228	0.0263
MIN	0.0040	0.0020	0.0170	0.0090	-0.064	-0.078
MAX	0.323	0.326	0.487	0.484	0.211	0.176
T					-0.70	-0.42
					(0.48)	(0.68)

Sample Period: 82.10 -86. 8

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0158	0.0147	0.0302	0.0300	-0.0021	-0.0002
STD	0.0266	0.0107	0.0150	0.0178	0.0257	0.0118
MIN	0.0010	0.0010	0.0060	0.0060	-0.471	-0.029
MAX	0.477	0.104	0.076	0.104	0.074	0.128
T					-1.55	-0.34
					(0.12)	(0.73)

Table 4-5 (Continued)
Bid-Ask Spread of Spot Bills

Panel C: Subsample by Forecasting Errors

Unanticipated Increase in Money Supply

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0232	0.0204	0.0421	0.0417	-0.0027	-0.0004
STD	0.0342	0.0200	0.0361	0.0368	0.0282	0.0174
MIN	0.0010	0.0010	0.0060	0.0060	-0.471	-0.067
MAX	0.477	0.237	0.475	0.468	0.034	0.176
T					-1.72	-0.40
					(0.09)	(0.69)

Unanticipated Decrease in Money Supply

	BAS1	BAS2	BAL1	BAL2	DBAS	DBAL
MEAN	0.0262	0.0259	0.0493	0.0485	-0.0003	-0.0008
STD	0.0330	0.0350	0.0497	0.0501	0.0162	0.0167
MIN	0.0010	0.0020	0.0070	0.0080	-0.490	-0.078
MAX	0.323	0.326	0.487	0.484	0.211	0.128
T					-0.35	-0.82
					(0.72)	(0.41)

Notes:
BAS1 = pre-announcement bid-ask spread of short-term maturity bill
BAS2 = post-announcement bid-ask spread of short-term maturity bill
BAL1 = pre-announcement bid-ask spread of long-term maturity bill
BAL2 = post-announcement bid-ask spread of long-term maturity bill
DBAS = change in the bid-ask spread of short-term maturity bill
DBAL = change in the bid-ask spread of long-term maturity bill
T = t-statistics
Numbers in parentheses are marginal significance levels.

Conclusions

The effect of unanticipated changes in the weekly money supply on the Treasury bill forward and futures rates is examined. By considering only deliverable bills, the null hypothesis that the spot and futures market investors are not non-overlapping segregated group in that their expectation for the future interest movements are not significantly different with respect to the weekly money supply announcements can be tested.

Empirical results show that the possibility of market segmentation between the primary and derivative assets is not prevalent in the Treasury bill market. The hypothesis is rejected only for a segment of sample, that is, only when the market expectation is larger than the actual announced money supply. Even for that subsample, the amount of change in yield differential seems to be too small to reach any definite conclusion. The evidence also shows that the monetary policy affects the market reactions and the market expects the Federal Reserve to fulfill its announced monetary policy. Another distinctive behavioral characteristic is that the market follows the trend in the interest rates.

As a second issue in this chapter, a hypothesis for the bid-ask spread in the Treasury bill market is introduced to assess the information content of the Fed's money supply announcement. In almost all cases, the bid-ask spread of spot bills declined after announcement but none of them are statistically significant. Two interpretations are possible. First, the Fed's release of new monetary information does not contribute to the resolution of uncertainty, but at least it is not a

nuisance to the market. Another possible interpretation is that the market expectations for the weekly money supply is so efficient that the Fed's announcement does not contain valuable information for the future interest rate movement.

CHAPTER V
SUMMARY AND CONCLUSIONS

This dissertation consists of three related but independent essays on the nature of the risk premiums in the financial market. The main theme of three essays is the role of the risk premiums in determining asset prices.

Chapter II examines the characteristics of risk premiums in the foreign exchange market. More specifically, the propositions that the nature of risk premiums in the foreign exchange market is invariant with respect to the maturity of the forward contracts and the risk premiums in the forward exchange market move together in proportion to a single variable.

This first objective is accomplished by applying the joint Generalized Method of Moments (GMM) to the overlapping samples of different maturities. Various tests on the nature of risk premiums in the foreign exchange market are possible only with overlapping samples since the size of non-overlapping sample for long maturity forward contracts is too small to provide reliable statistical inferences. Statistical problems arising from using overlapping sample (serial correlation and conditional heteroscedasticity) are corrected by utilizing the Generalized Method of Moments (GMM).

From the joint GMM estimations and tests across 9 currencies and across 4 maturities, we are able to reach the following conclusions. First, forward exchange rates have some predictive power for the future

spot exchange rates movements, but they are not perfect predictors and there exist time-varying risk premiums. Second, variations in the risk premiums rather movements in expected spot exchange rate changes account for most of the variation in the forward exchange rates. Third, the resolution of uncertainty in the foreign exchange market is not uniform across maturity, and there exists maturity-specific information the market participants can use in their investment decisions.

The second proposition can be tested by extending a single constant beta model to a latent variable model in the context of the Intertemporal Capital Asset Pricing Model (ICAPM). The proposition that risk premiums in the forward exchange rates are moving together is tested by implementing non-linear cross-equation restrictions. Under the latent variable model of risk premiums, the pricing of risk premiums in the forward exchange rates is assumed to be driven by a single latent benchmark portfolio.

For the cross-currency estimation of latent variable model, we obtained mixed and inconclusive results. However, for the cross-maturity estimation, the restrictions of the latent variable model are not rejected for all exchange rates of different maturities. Consistent with our intuition, long maturity forward rates contain more risk premiums than short maturity forward rates.

Chapter III examines the effect of the Federal Reserve's weekly money supply announcement on the foreign exchange rates and risk premiums under the international capital market equilibrium. Joint estimation of the spot and the forward exchange markets of different maturities makes it feasible to test additional testable restrictions which should be held in equilibrium. Particularly, the possibility of

overshooting of spot exchange rates is considered in testing hypotheses. This possibility is due to differential price adjustments between financial and commodity markets. In other words, spot exchange rates may overreact to compensate for the slow adjustment in the commodity markets to unexpected changes in money supply. The empirical results show that the spot exchange rates and risk premiums increase simultaneously after unexpected increase in the money supply. This evidence is consistent with the hypothesis suggested by the interest rate parity theory and the real interest rate theory of money supply announcement effect. It is also found that the Federal Reserve's stated monetary policy significantly affects the market participants' reaction to the unanticipated money supply changes.

Chapter IV includes two studies in the Treasury bill spot and futures markets. The first study addresses the price relationship between the primary and derivative assets in the Treasury bill markets. Market efficiency in the Treasury bill markets dictates no arbitrage opportunity between the spot and futures markets. By examining the changes in the yields differentials between the Treasury bill forward and futures contracts, the hypothesis of market segmentation between the spot and futures markets is tested. The market segmentation in this study means that investors in the two markets are distinct nonoverlapping groups and their expectations for the future interest rates and hence risk premiums are different with respect to the release of monetary information by the Federal Reserve. The empirical evidence shows that the possibility of market segmentation is not prevalent in the Treasury bill markets, even though the market segmentation hypothesis is rejected for the subsamples of negative monetary shocks.

Even in that case, the amount of changes in yield differential is too small to reach the conclusion of market segmentation.

Secondly, the Treasury bill dealers' risk premium charging behavior with respect to the monetary uncertainty is examined. Risk premium component in the security dealer's bid-ask spreads is the compensation for the expected losses of inventory value of securities from unexpected fluctuations of interest rates. By testing whether the bid-ask spread changes around the money supply announcements are significant, the information contents of the Federal Reserve's weekly money supply announcements and the Treasury bill dealers' premium charging behavior are investigated.

In almost all cases, the bid-ask spread of spot bills decline after announcements, but none of them are statistically significant. Two interpretations are suggested. First, the Fed's release of new monetary information does not contribute to the resolution of uncertainty. Another explanation is that the market expectations for the weekly money supply is so efficient that the Fed's announcement does not contain valuable information for the future interest rate movement.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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